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H0498.70187US01

NANOSCALE WIRES AND RELATED DEVICES

By: Charles M. Lieber, et al.

Express Mail Label No.: EV292456372US

Date of Deposit: November 21, 2003

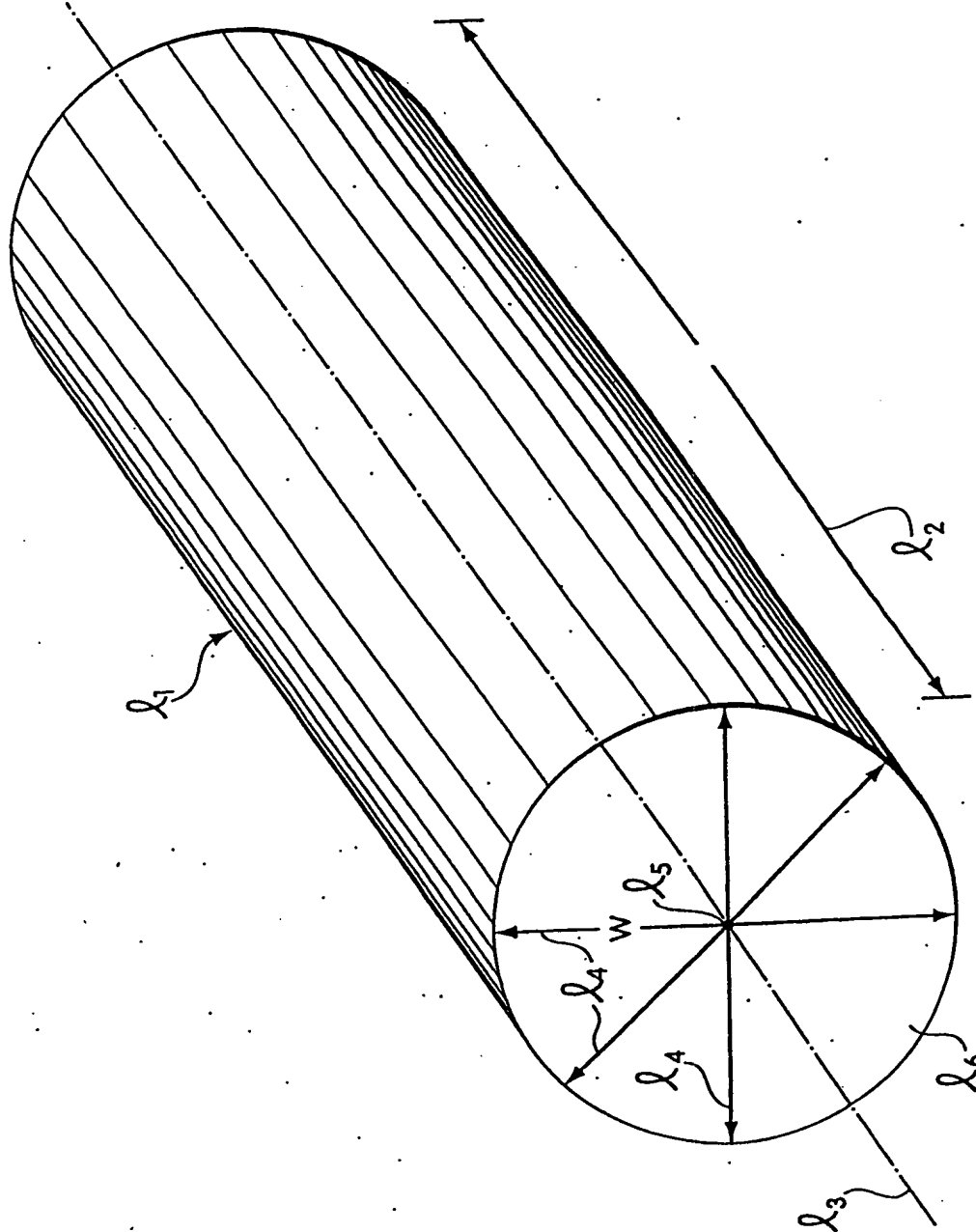


Fig. 1

H0498.70187US01

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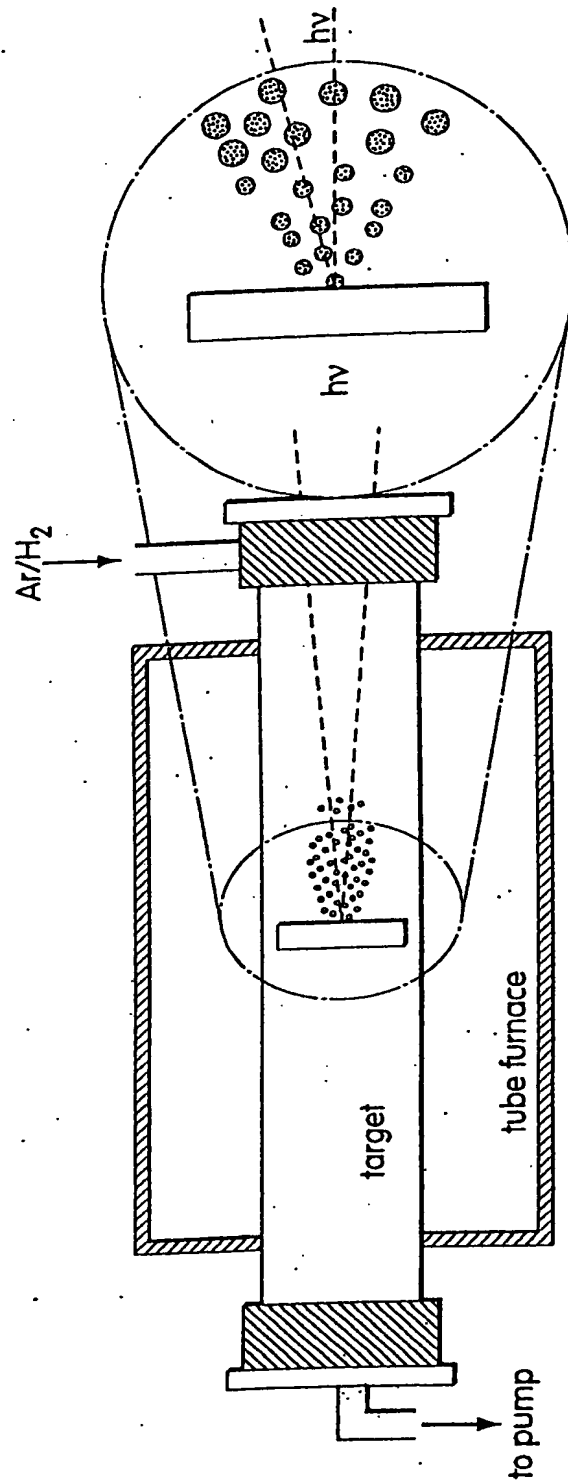


Fig. 2

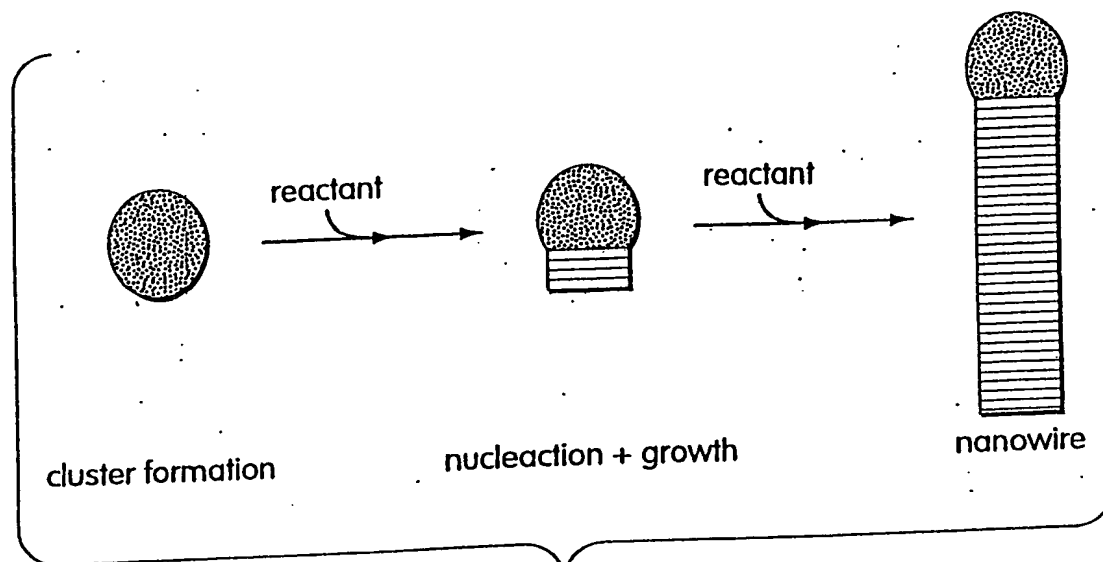


Fig. 3

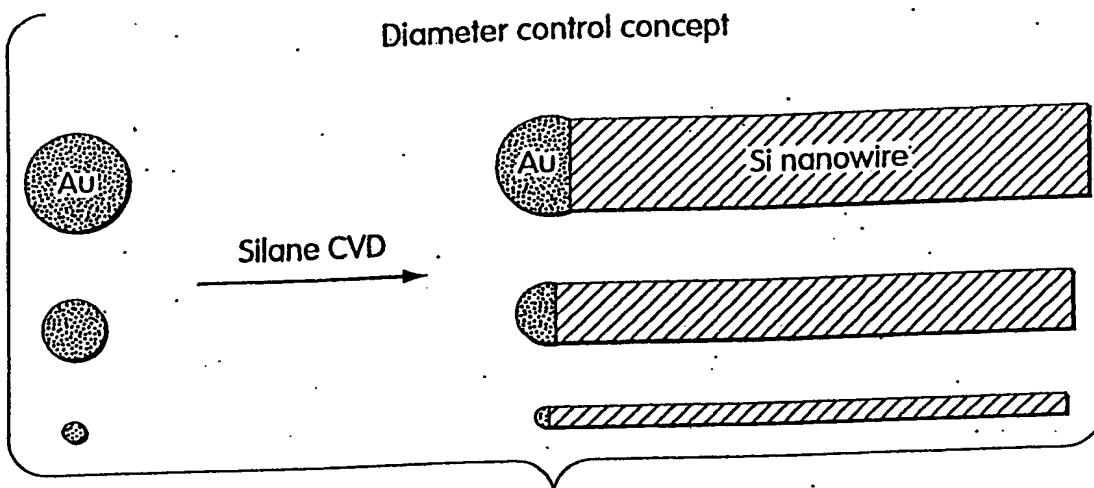


Fig. 4

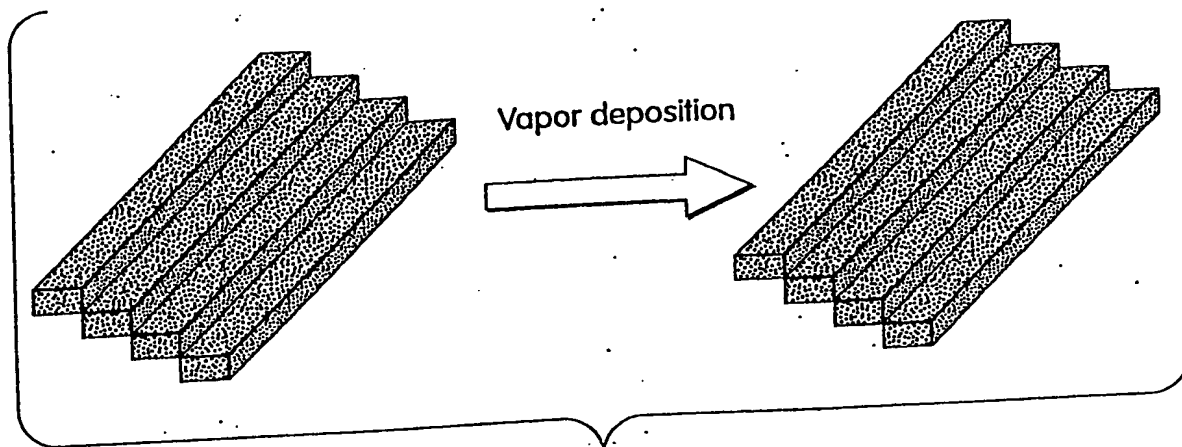


Fig. 5

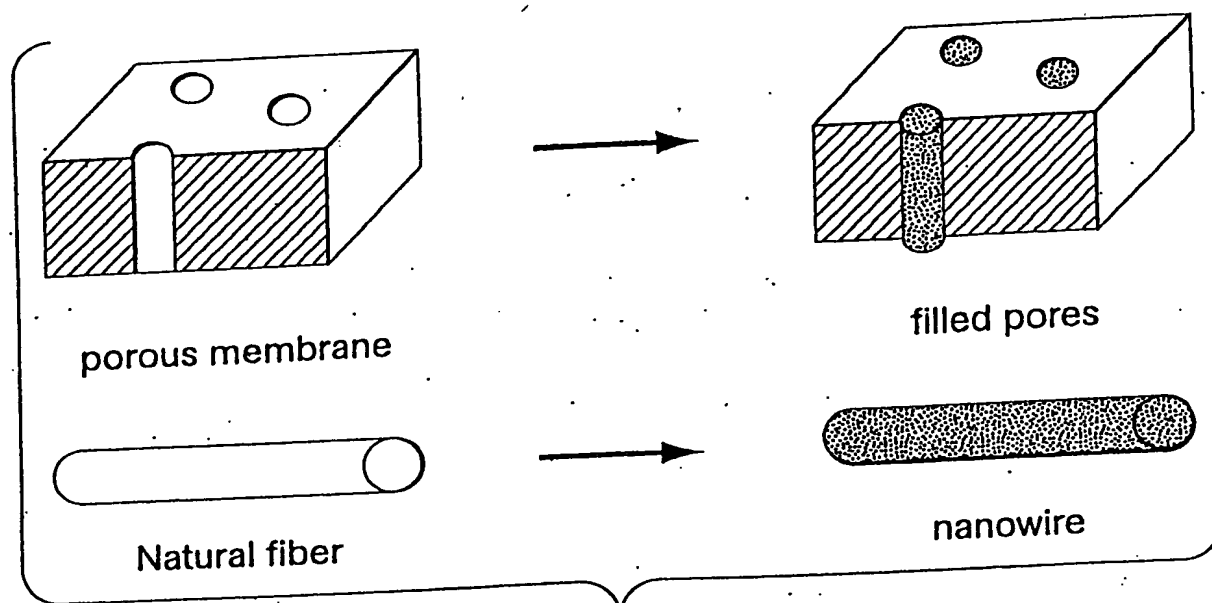


Fig. 6

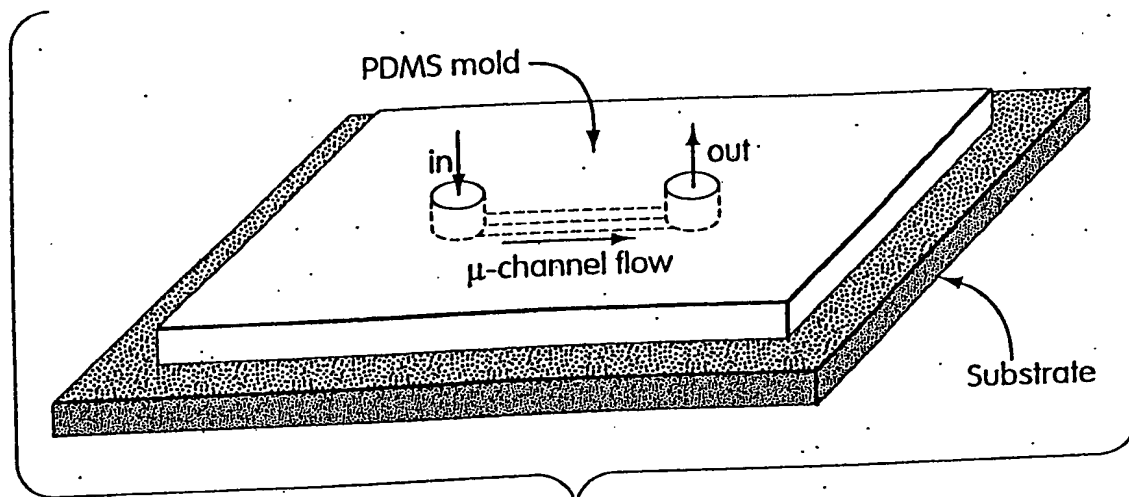


Fig. 7A

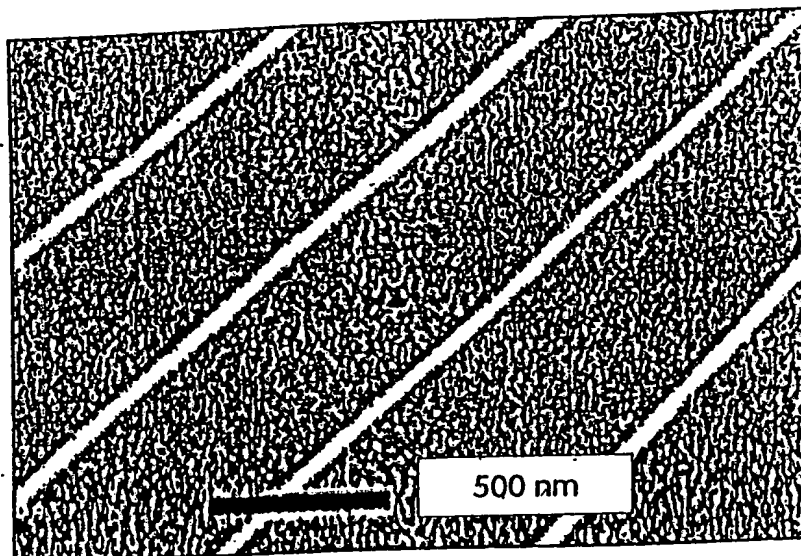


Fig. 7B

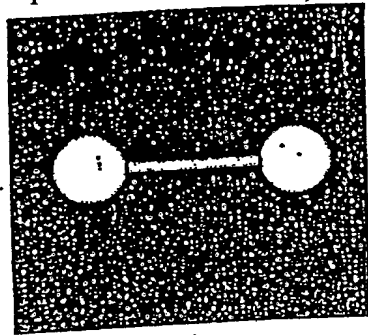
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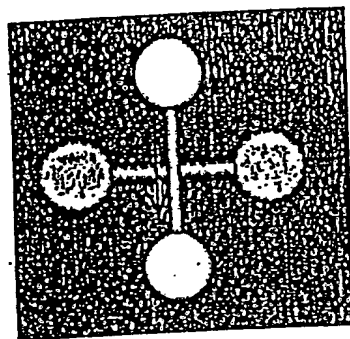
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First layer

Fig. 7C



Second layer

Fig. 7D

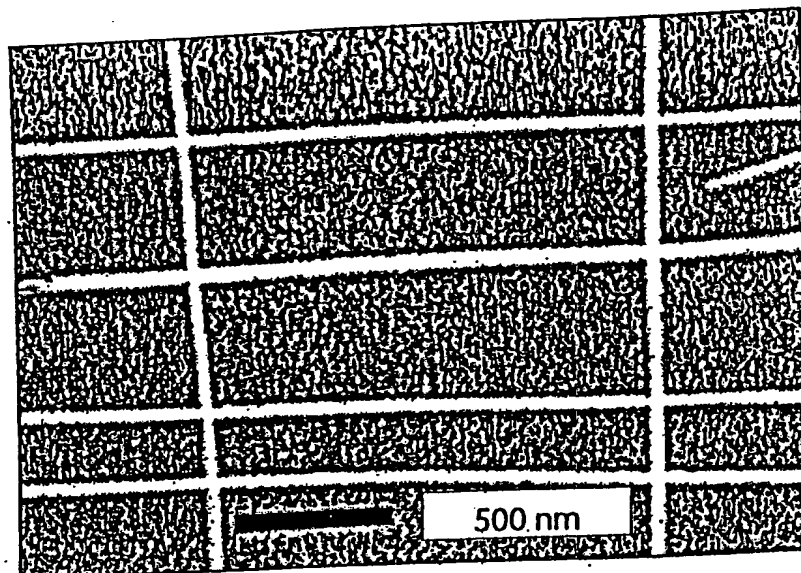


Fig. 7E

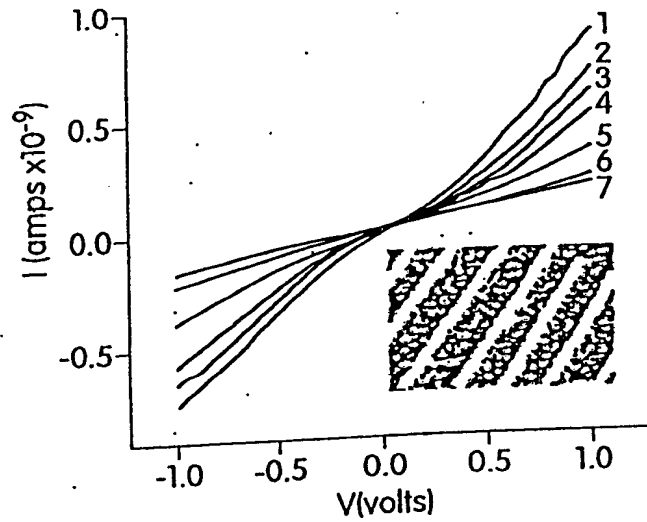


Fig. 8A

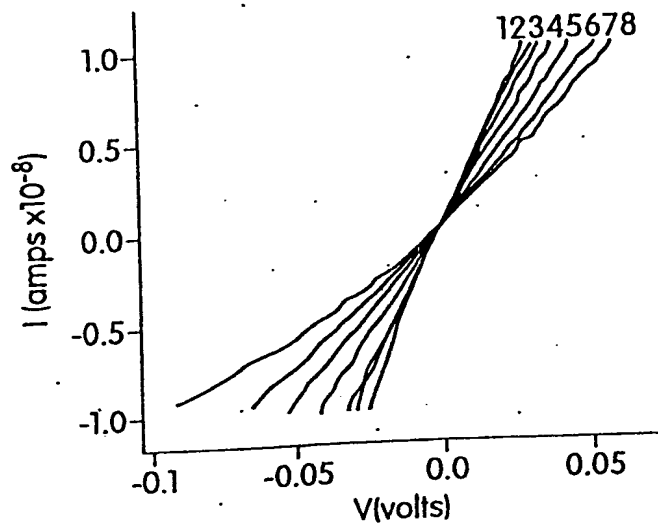


Fig. 8B

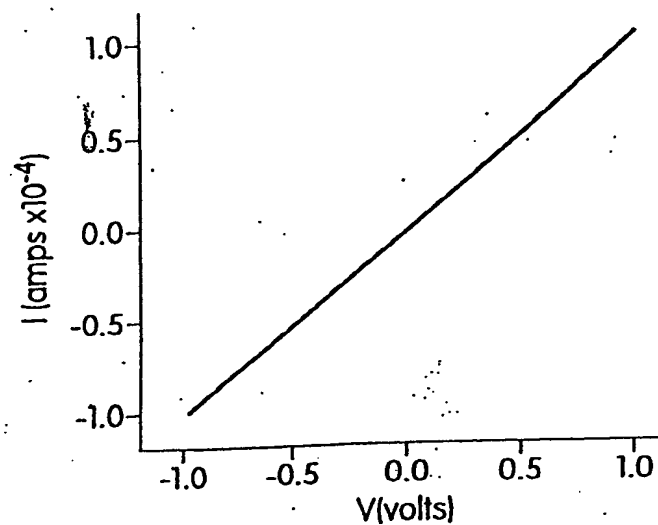


Fig. 8C



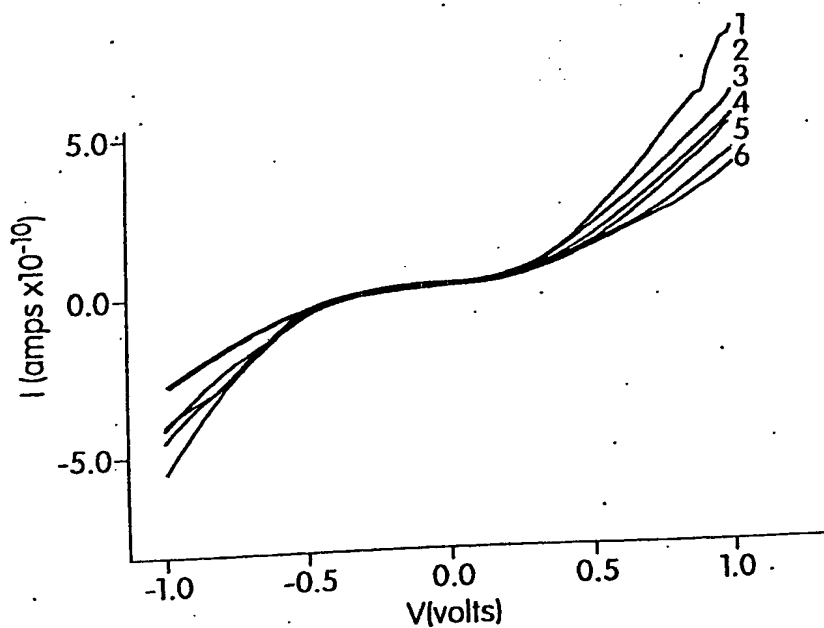


Fig. 9A

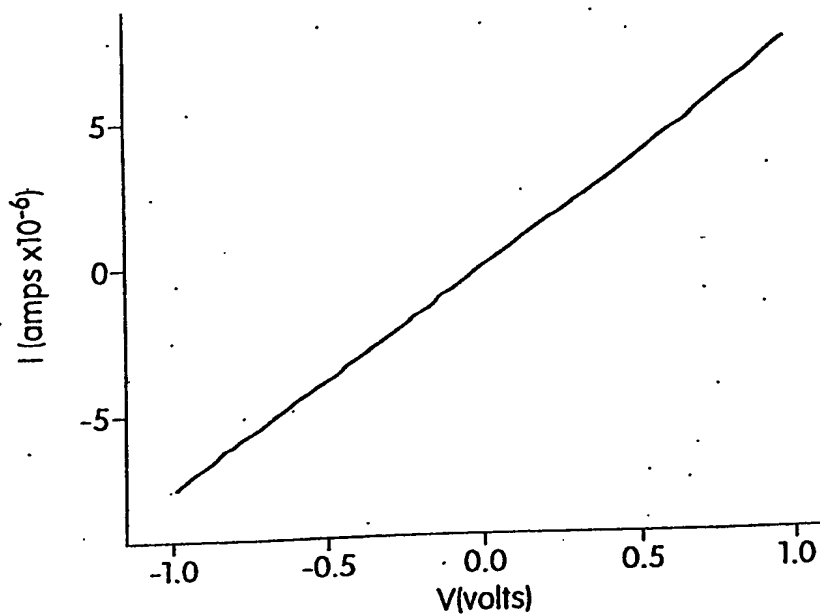


Fig. 9B

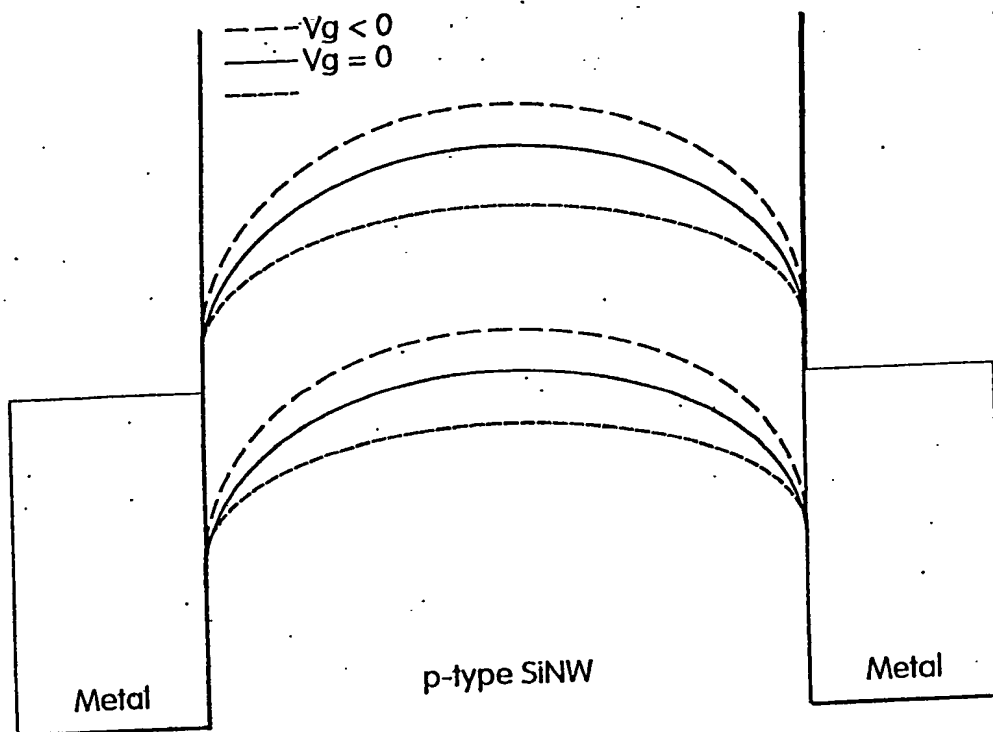


Fig. 10A

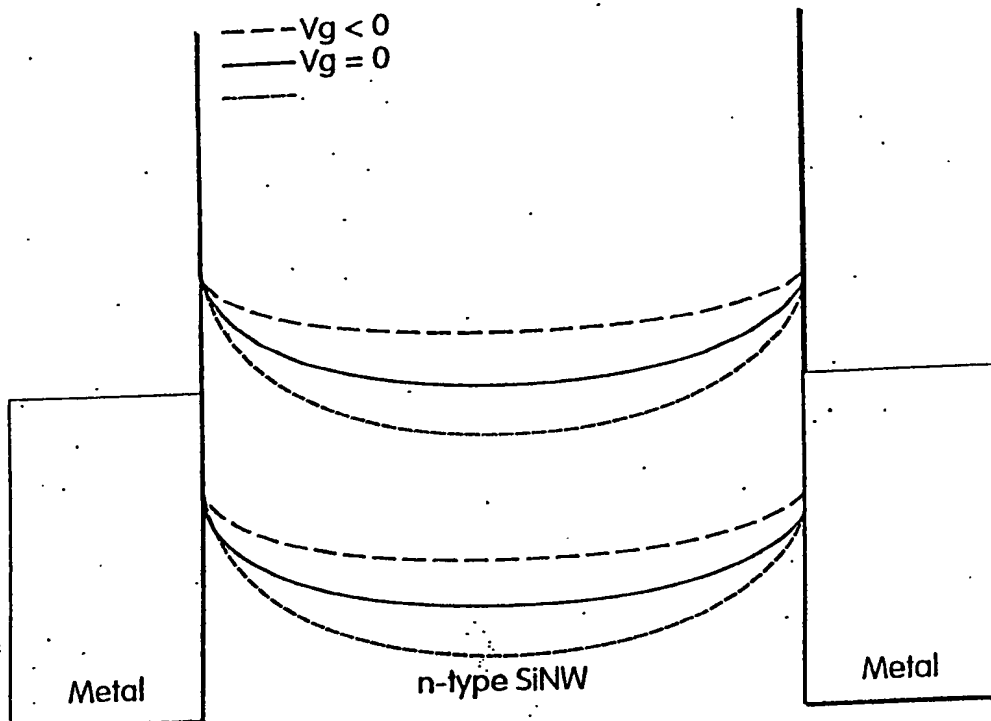


Fig. 10B

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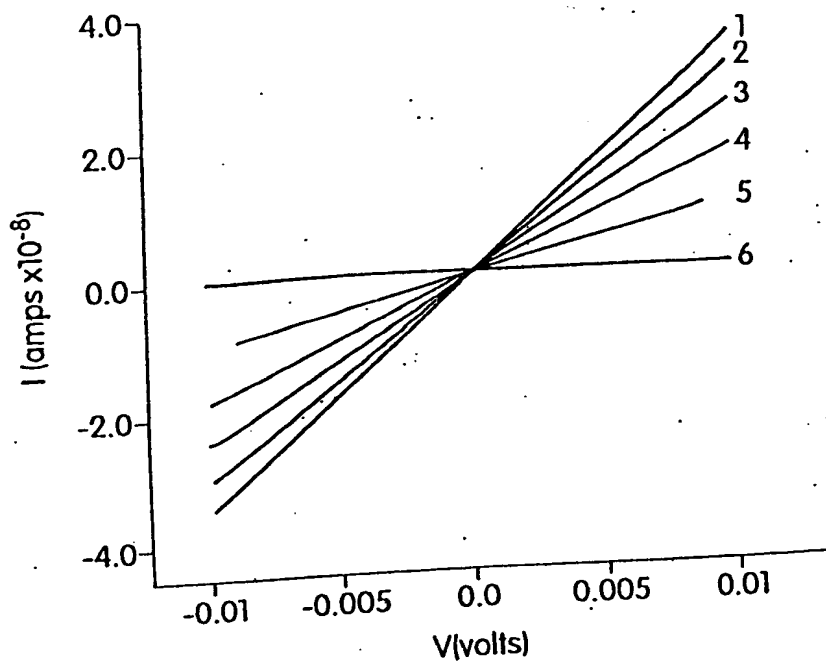


Fig. 11A

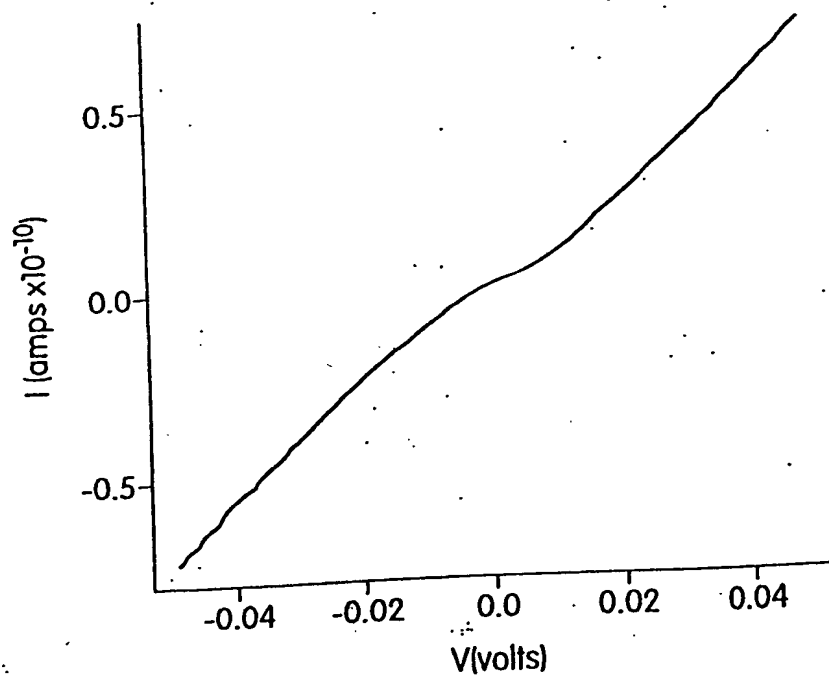


Fig. 11B

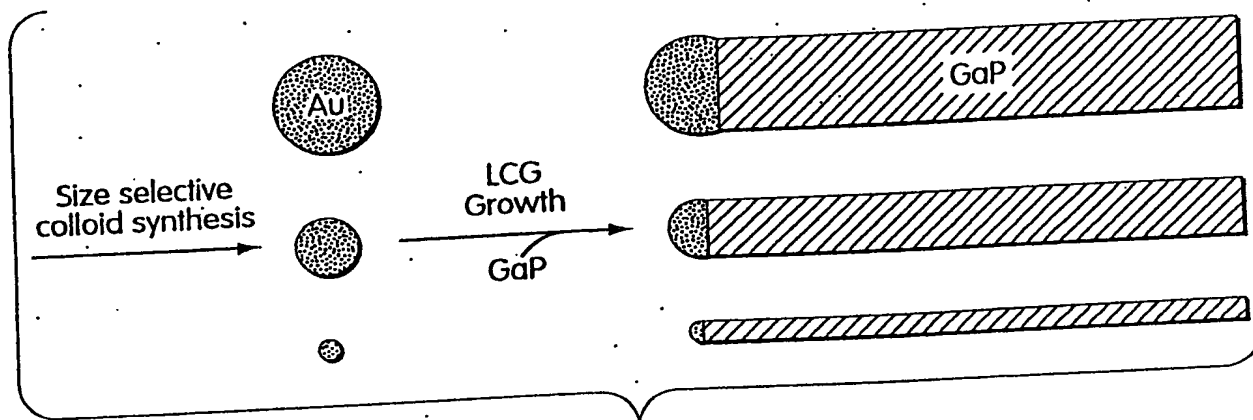


Fig. 12

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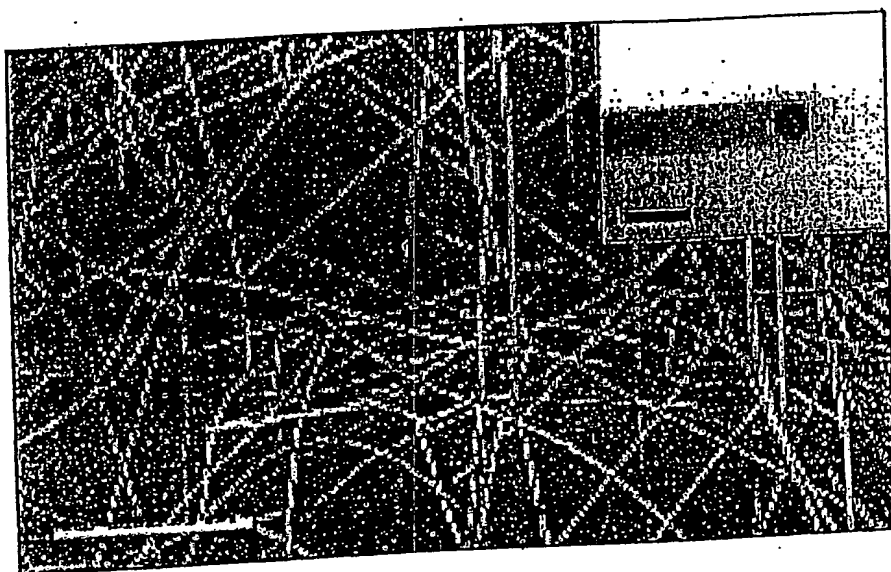


Fig. 13A

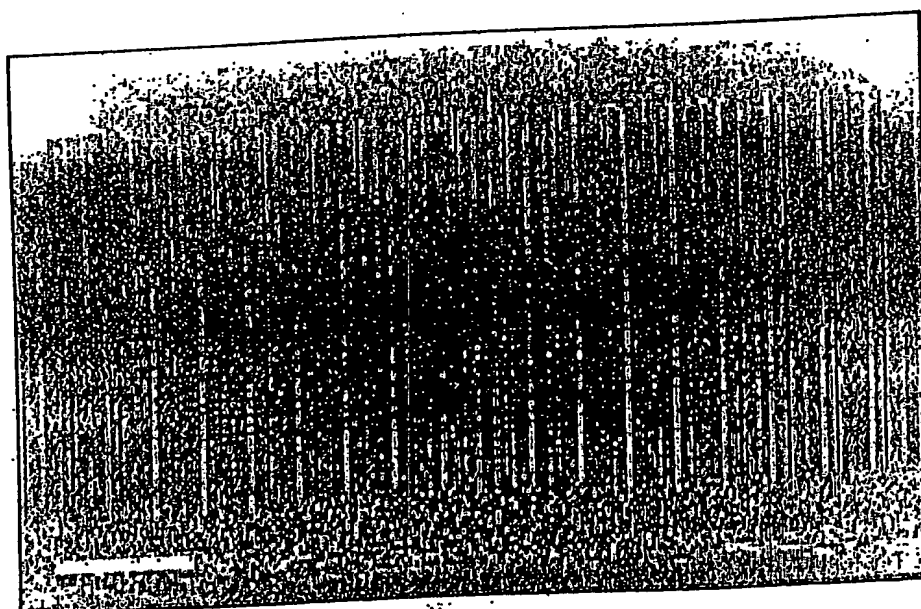


Fig. 13B

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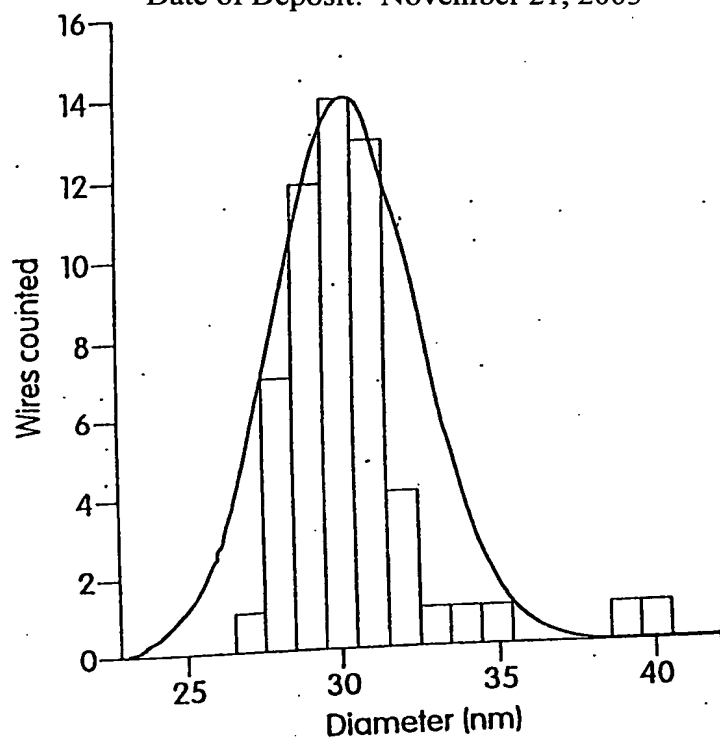


Fig. 14A

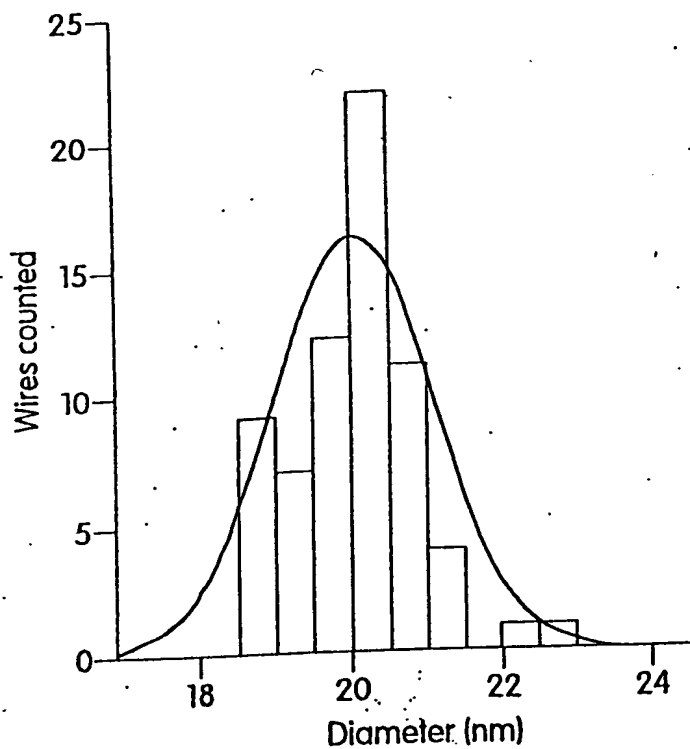


Fig. 14B

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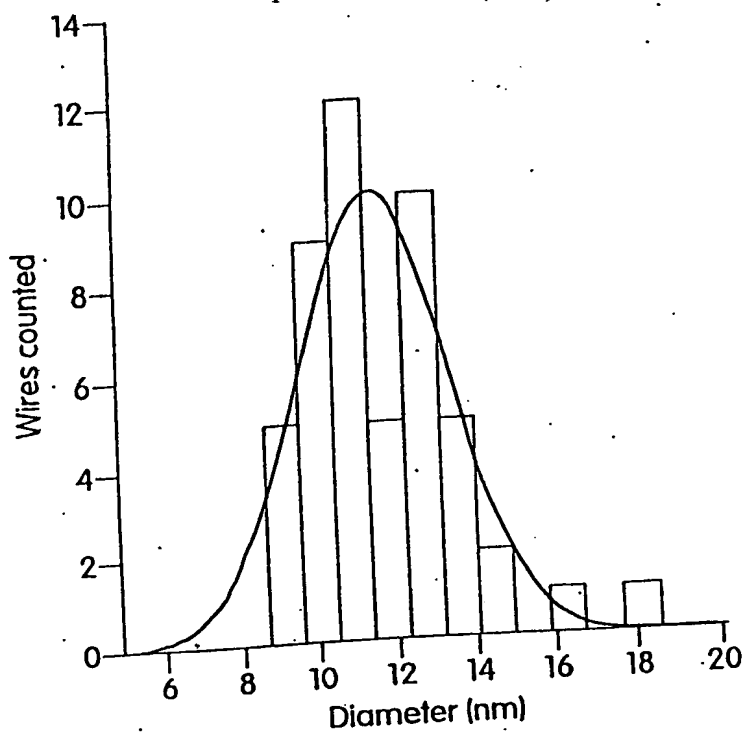


Fig. 14C

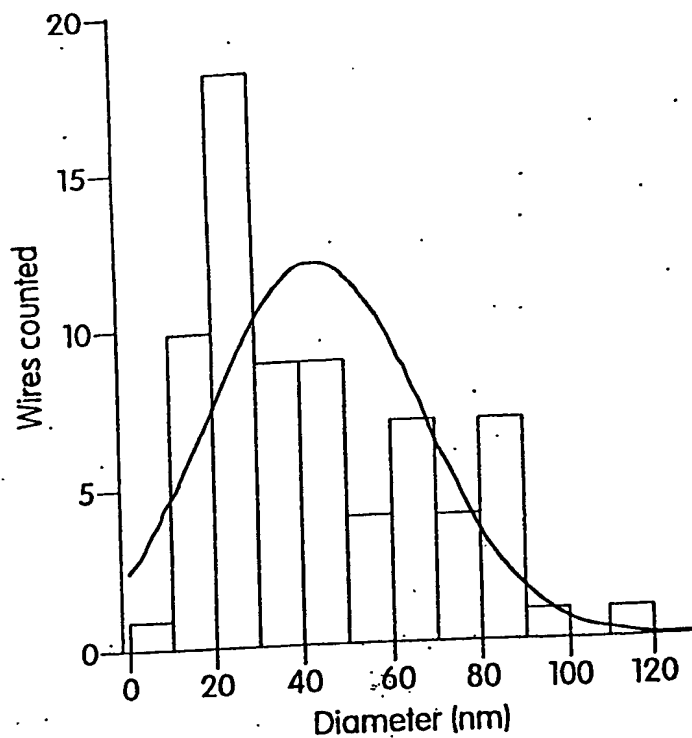


Fig. 14D

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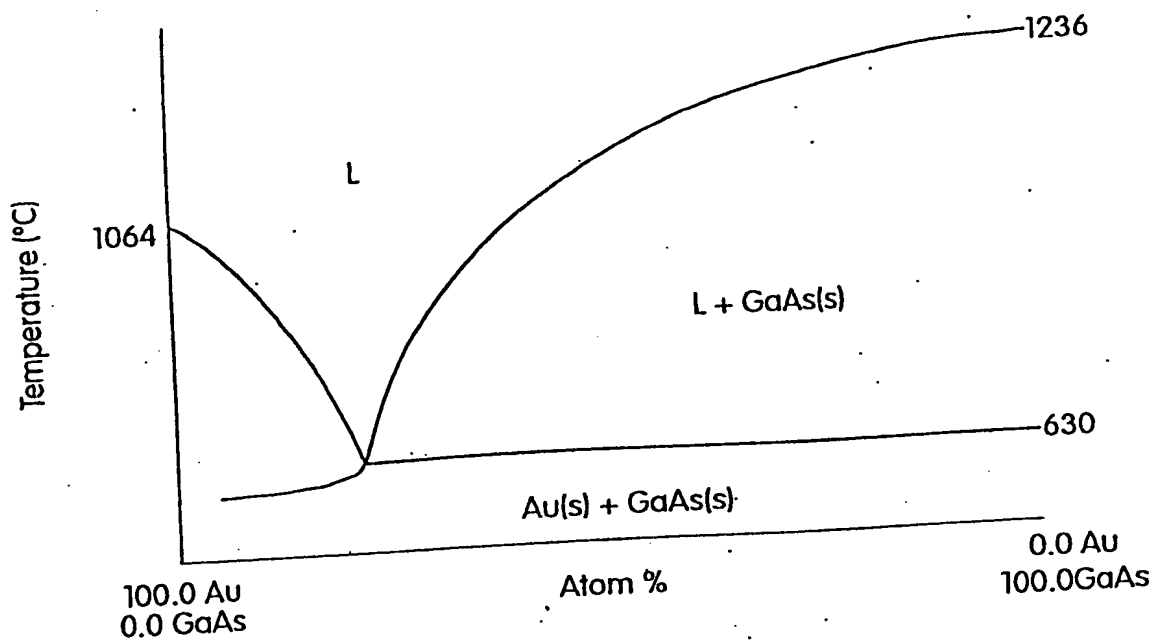


Fig. 15



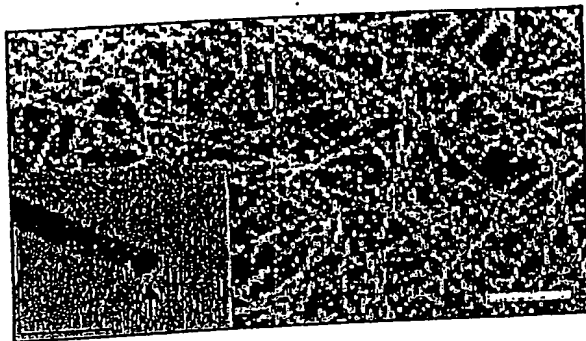


Fig. 16A



Fig. 16B

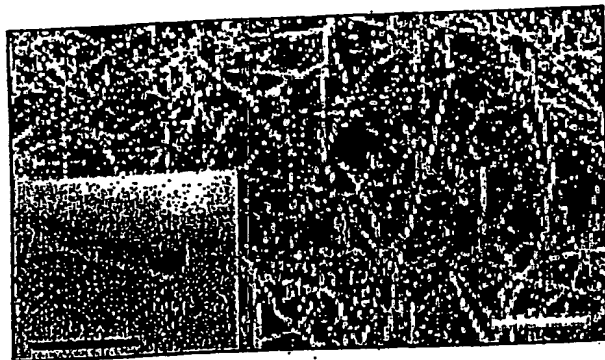


Fig. 16C

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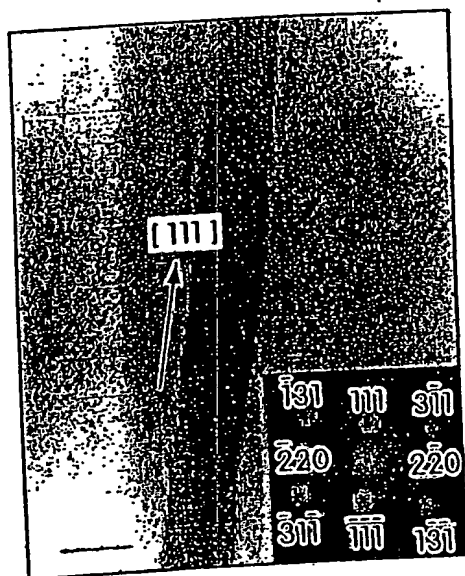


Fig. 17A

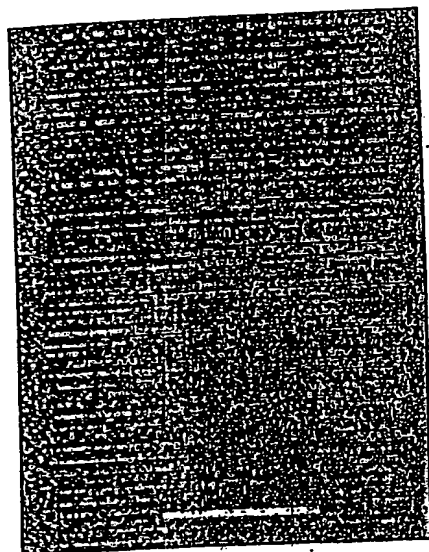


Fig. 17B

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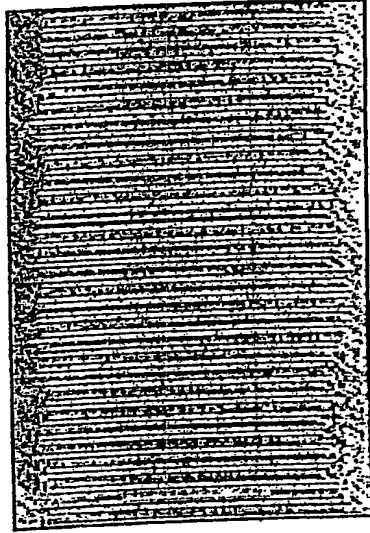


Fig. 17C



Fig. 17D

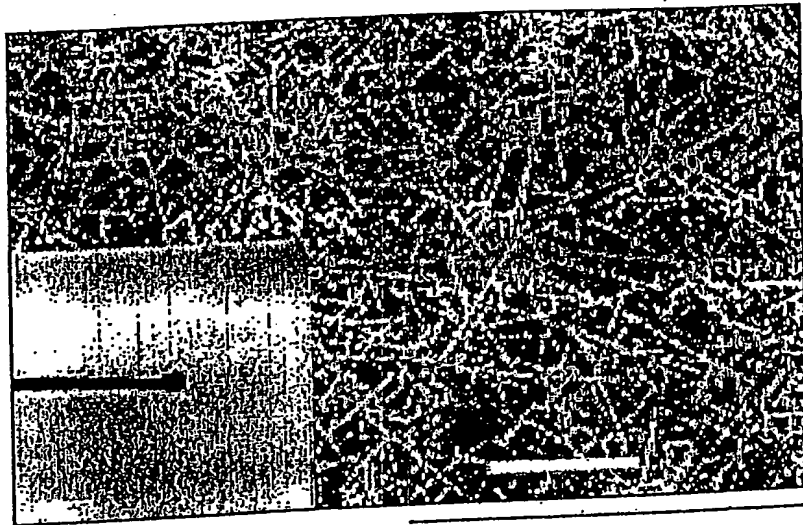


Fig. 18A

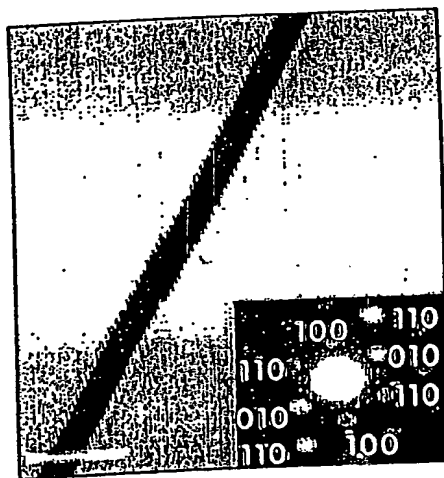


Fig. 18B

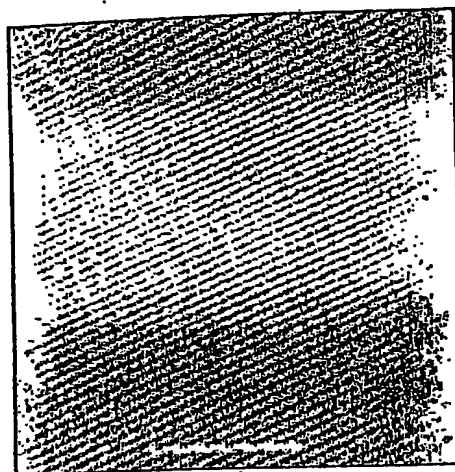


Fig. 18C

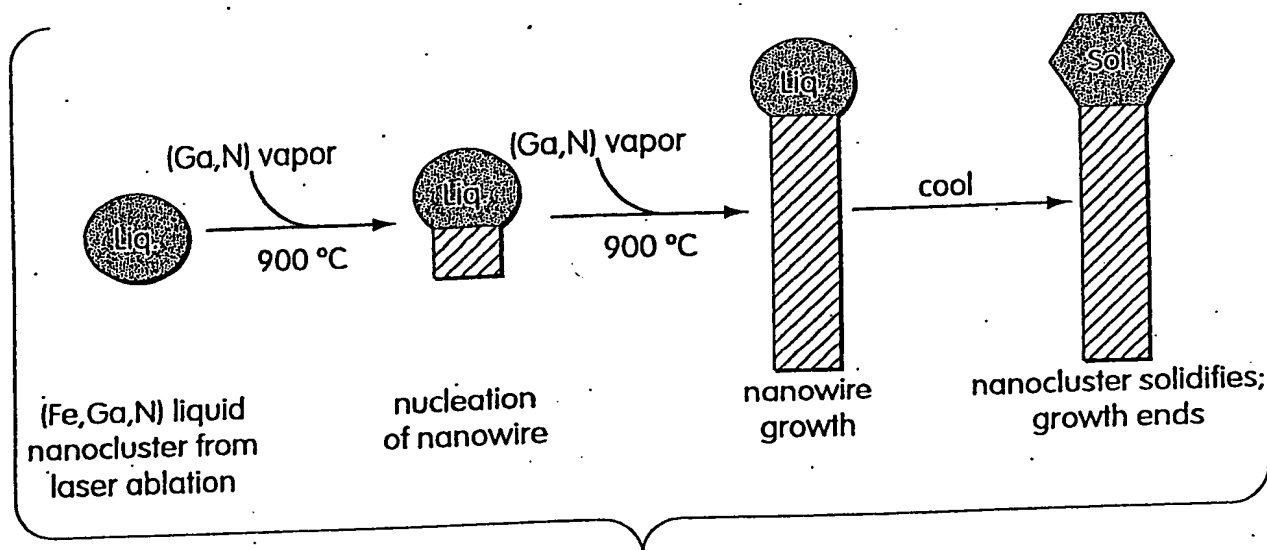


Fig. 19

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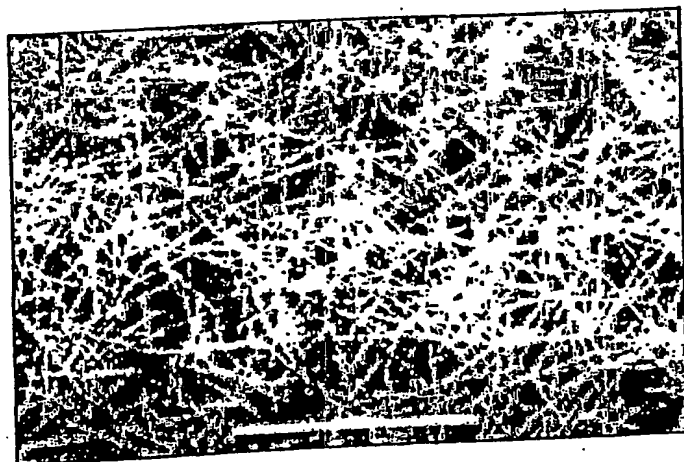


Fig. 20A

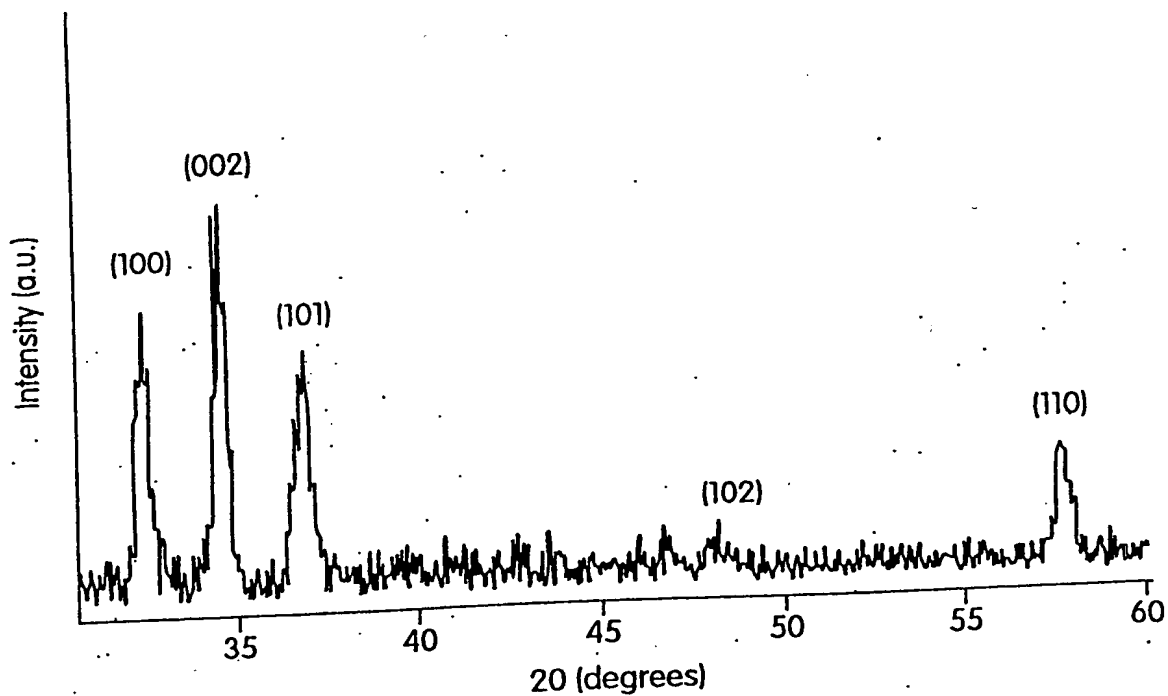


Fig. 20B

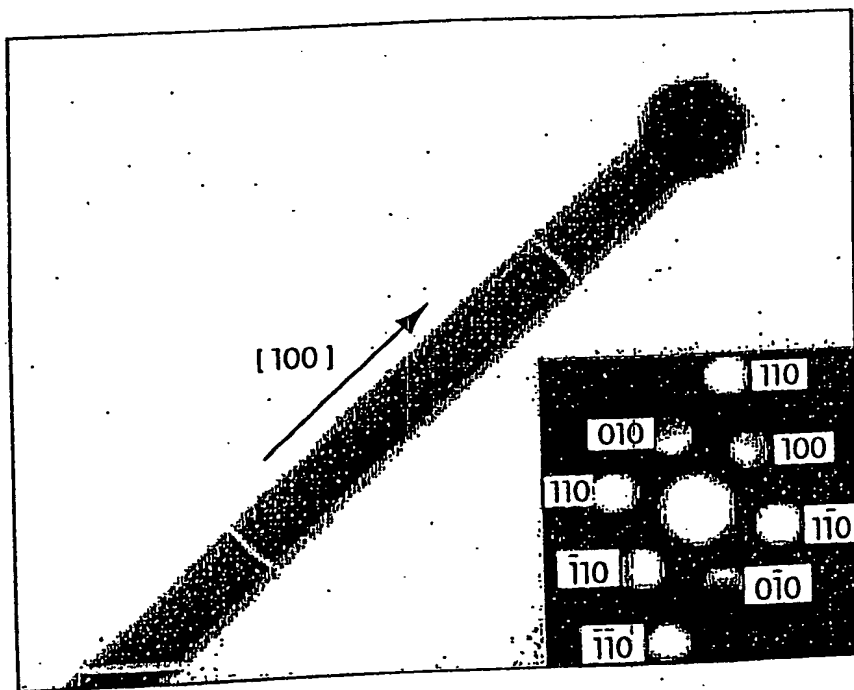


Fig. 21A

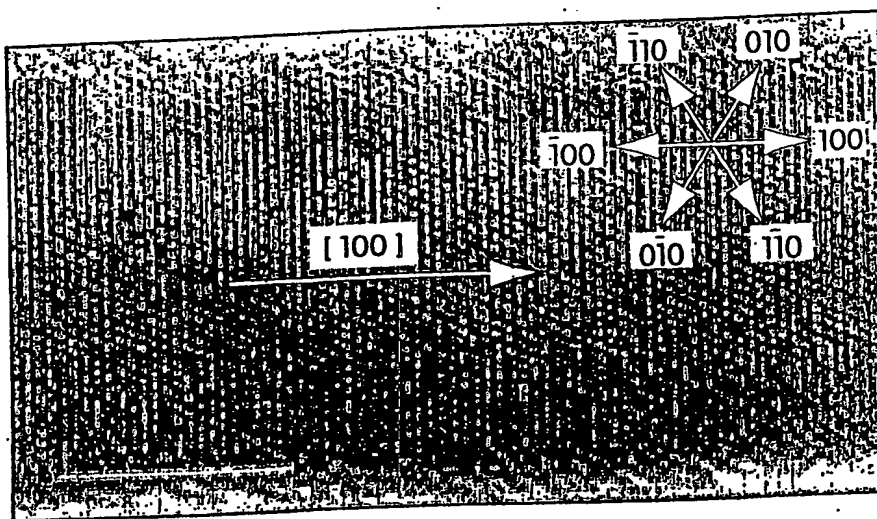


Fig. 21B

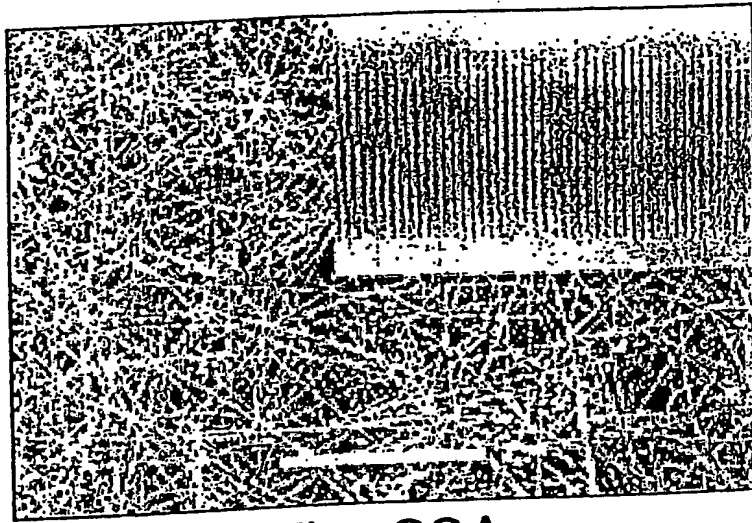


Fig. 22A

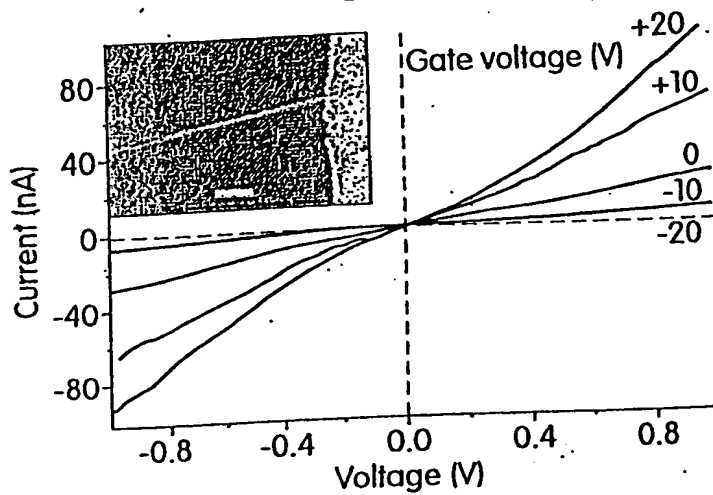


Fig. 22B

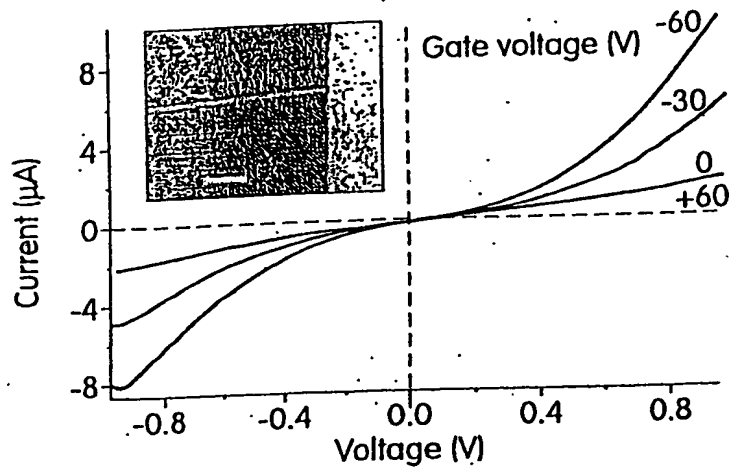


Fig. 22C



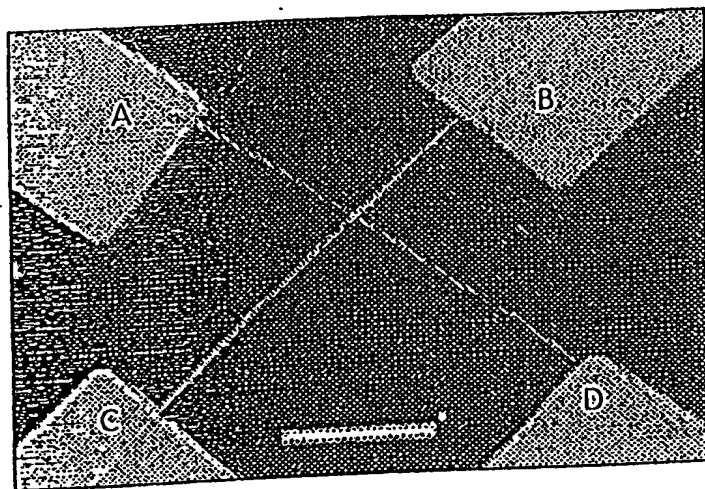


Fig. 23A

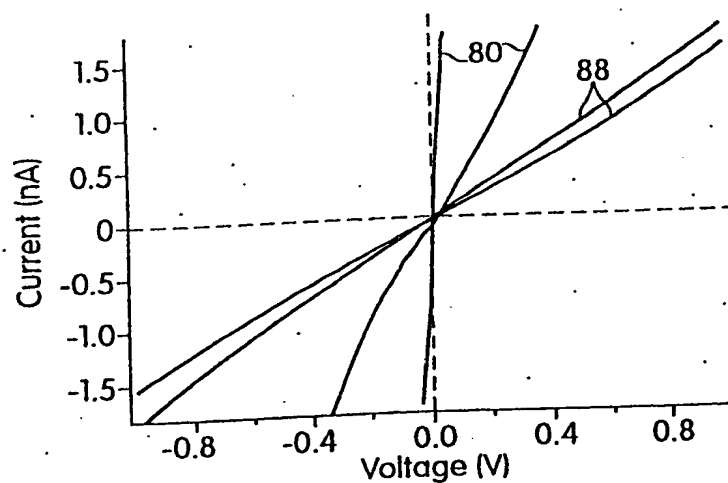


Fig. 23B

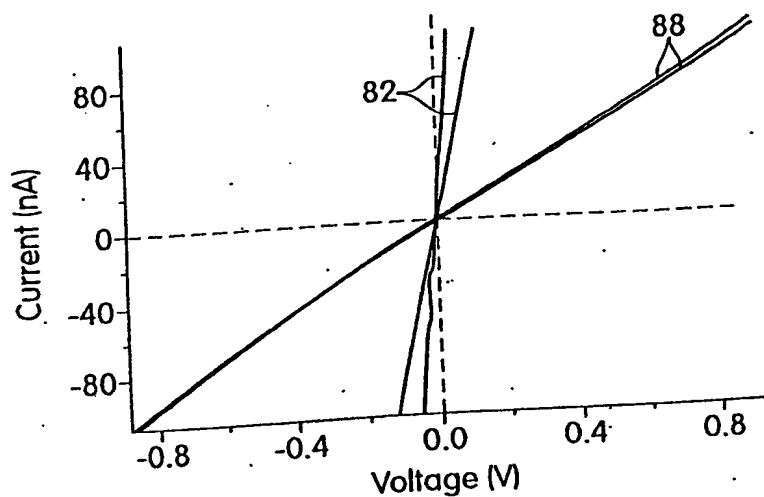


Fig. 23C

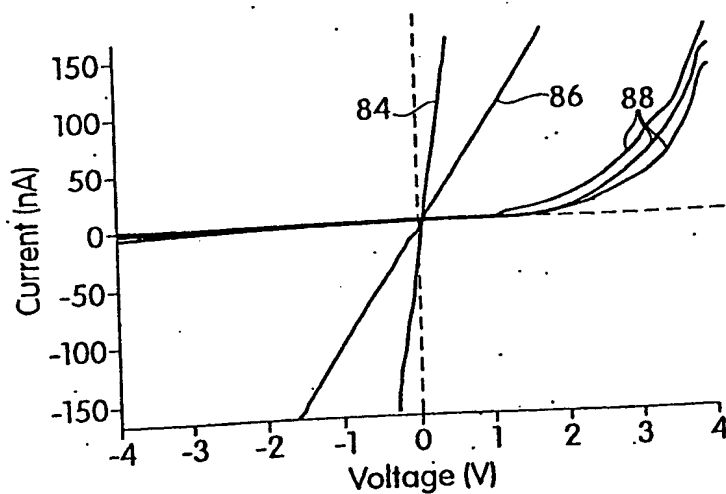


Fig. 23D

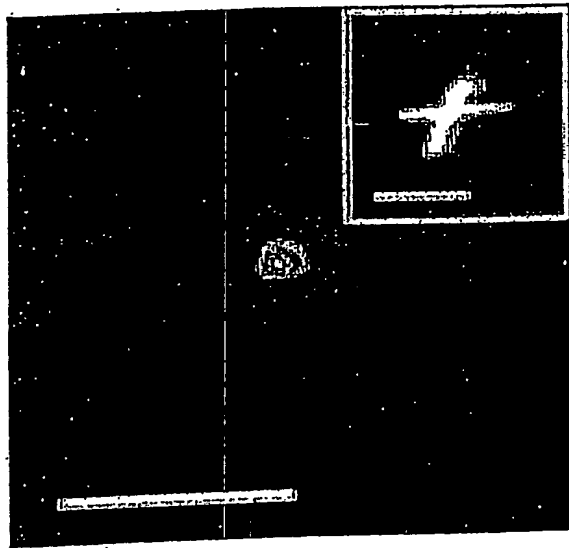


Fig. 24A

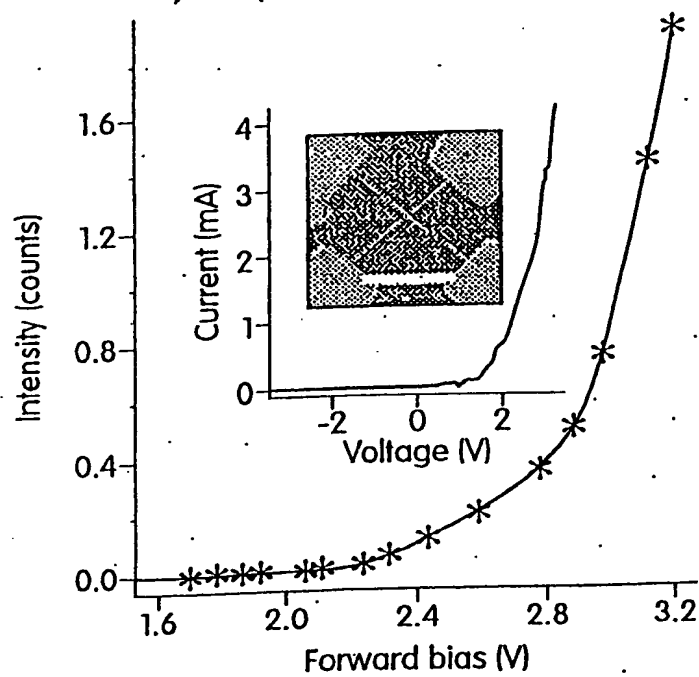


Fig. 24B

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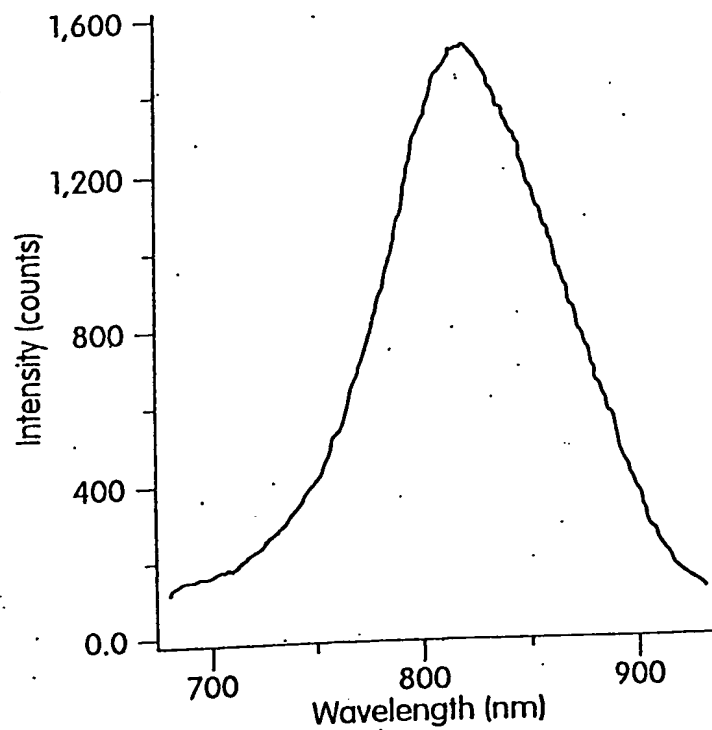


Fig. 24C

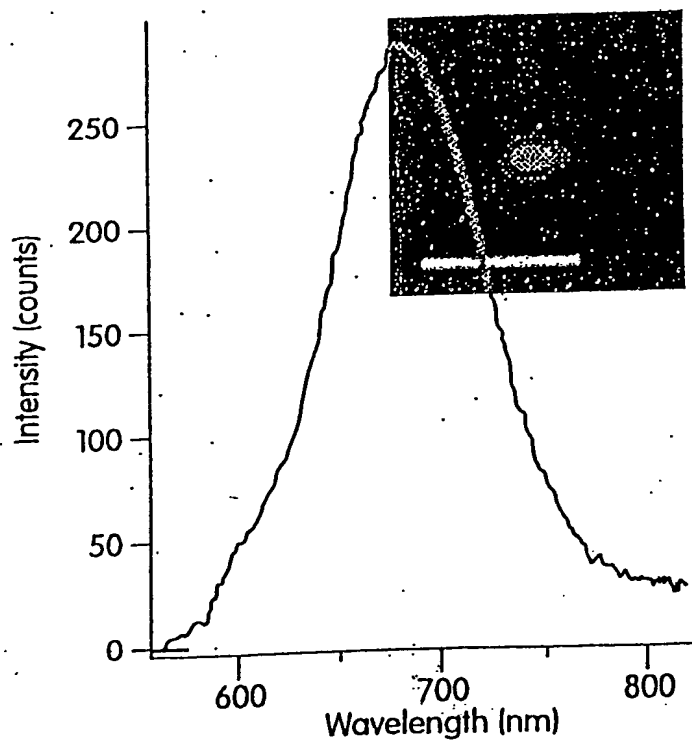


Fig. 24D

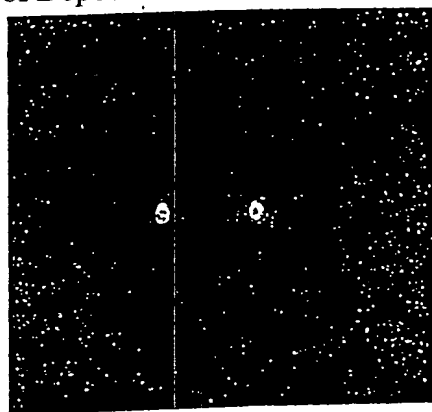


Fig. 25A

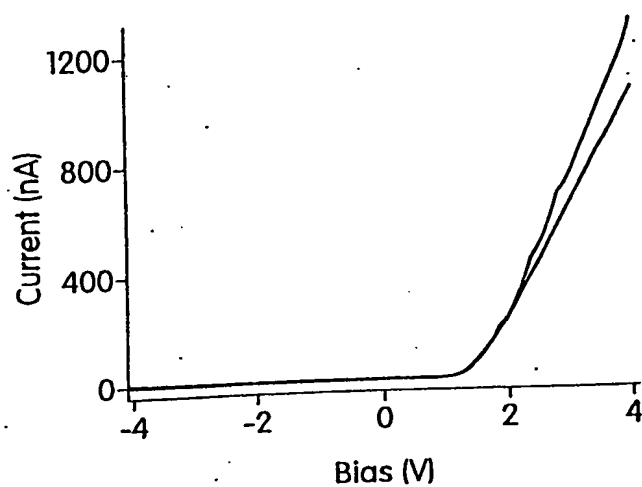


Fig. 25B

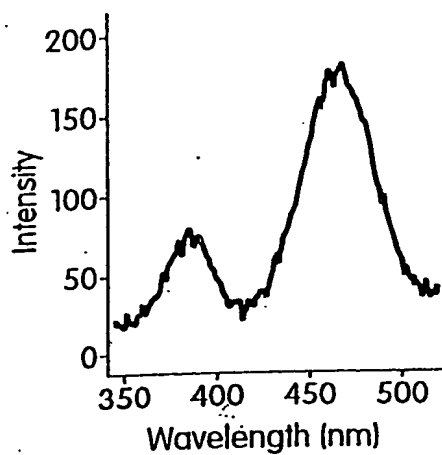


Fig. 25C

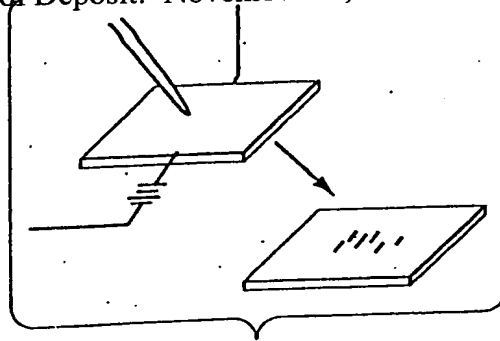


Fig. 26A

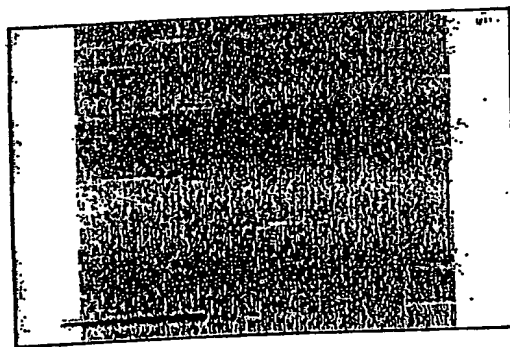


Fig. 26B

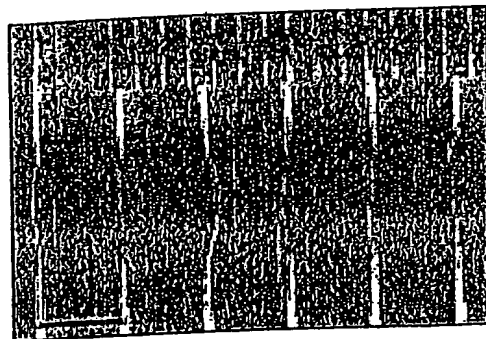


Fig. 26C

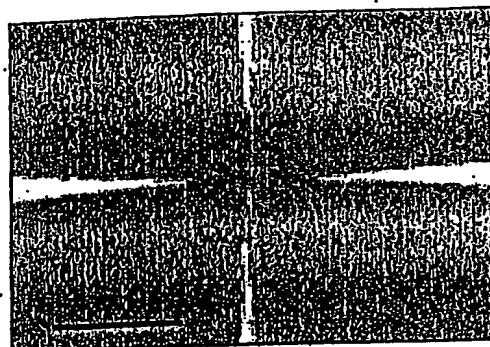


Fig. 26D

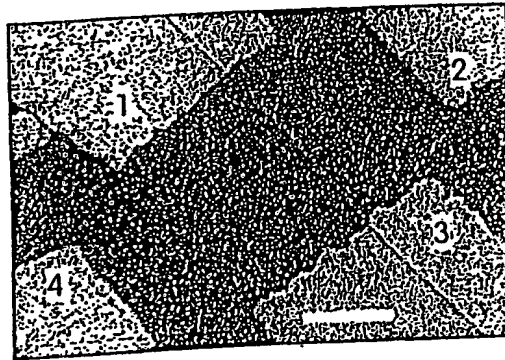


Fig. 27A

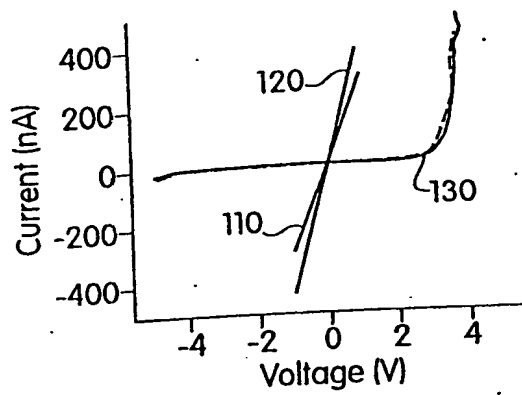


Fig. 27B

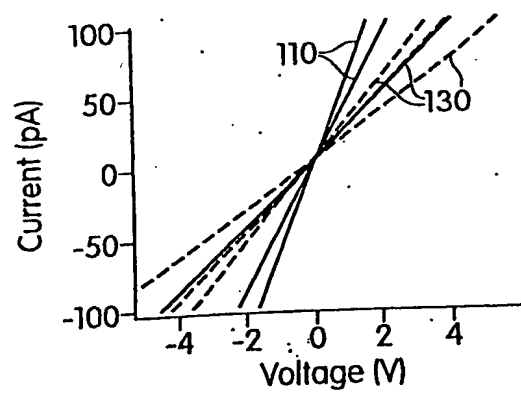


Fig. 27C

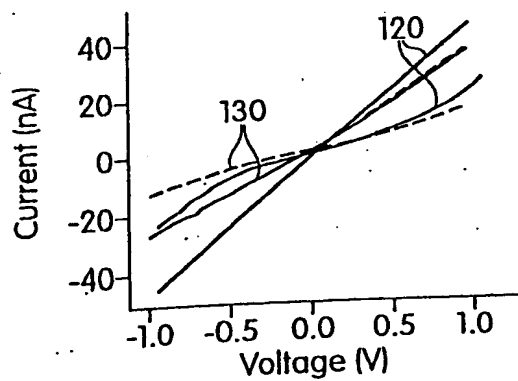
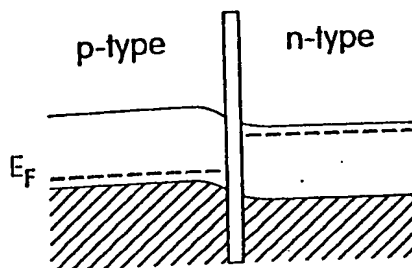
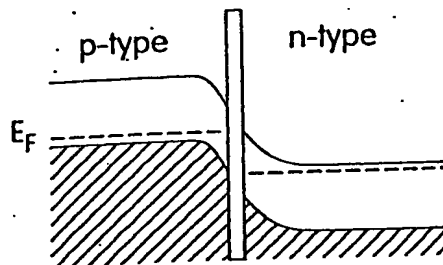


Fig. 27D



Forward bias

Fig. 27E



Reverse bias

Fig. 27F



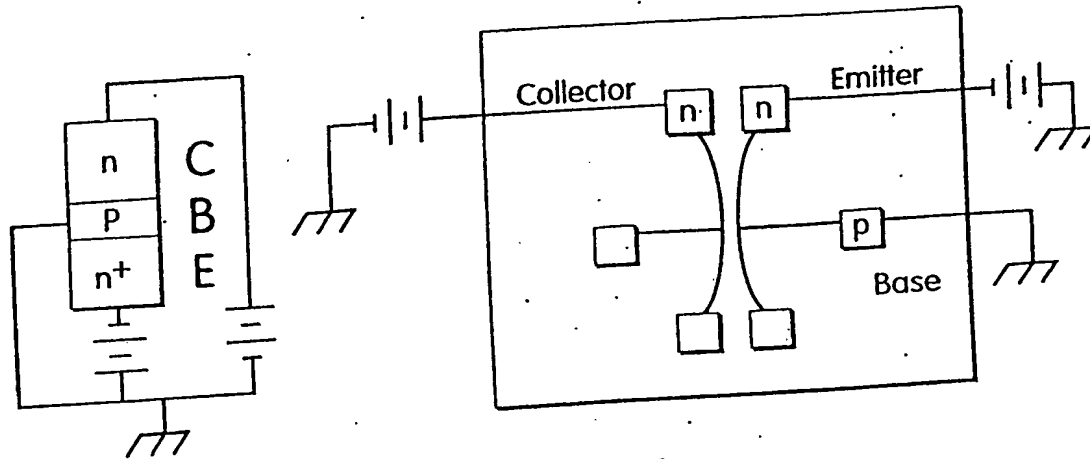


Fig. 28A

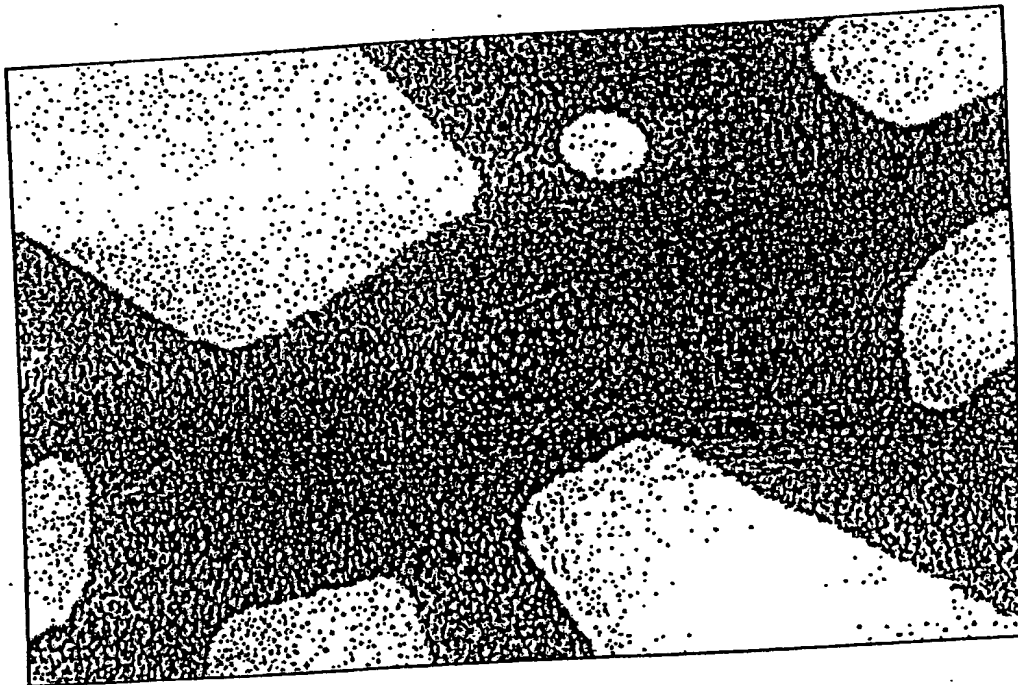


Fig. 28B

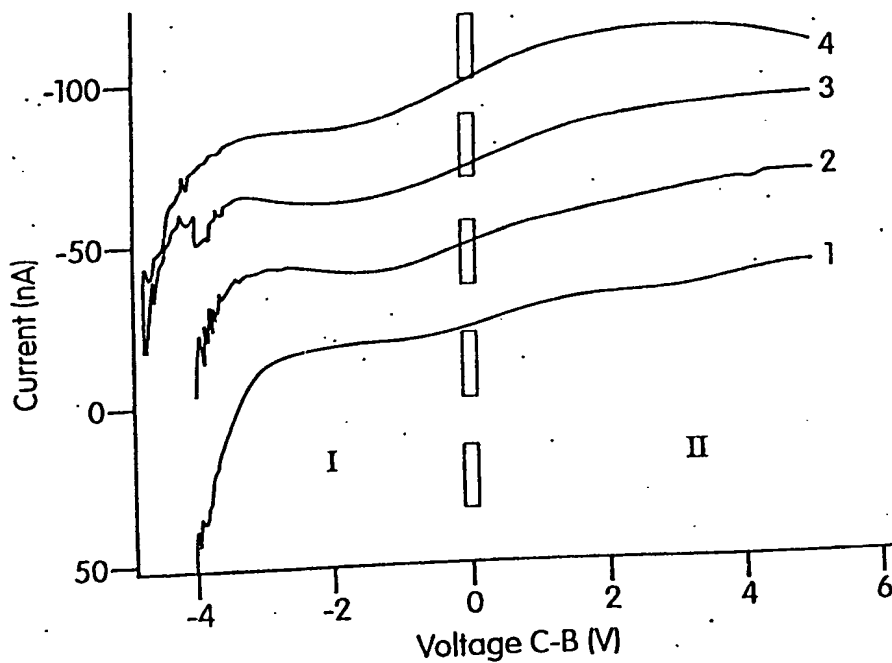


Fig. 28C

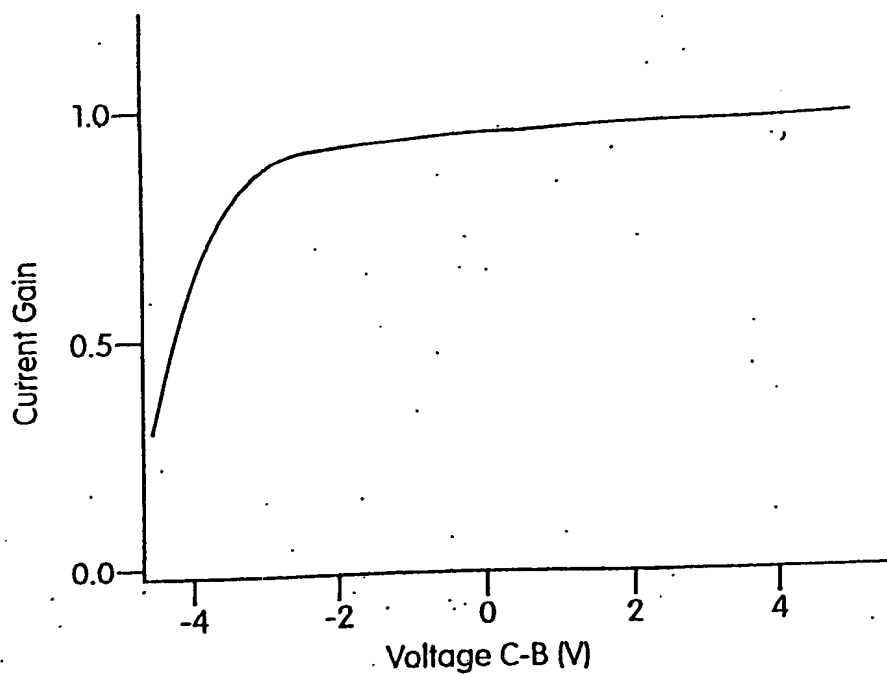


Fig. 28D

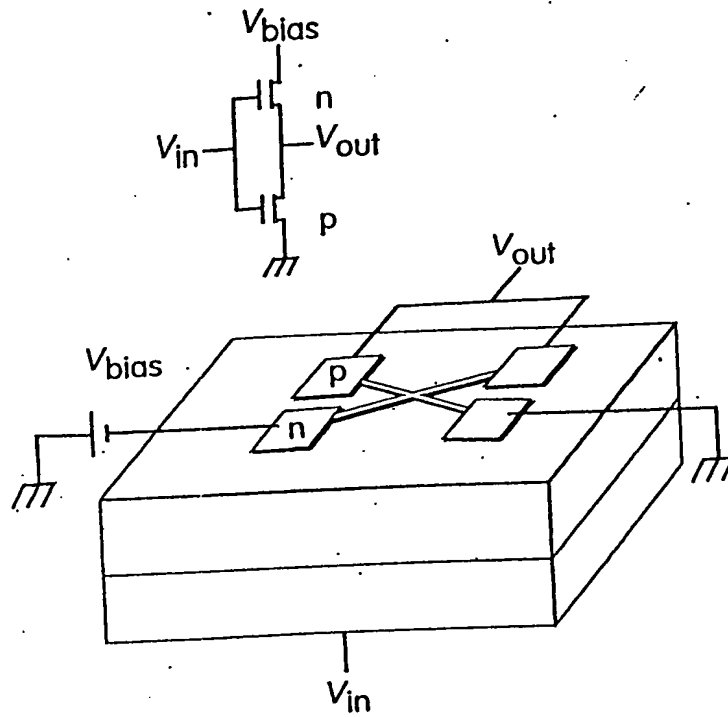


Fig. 29A

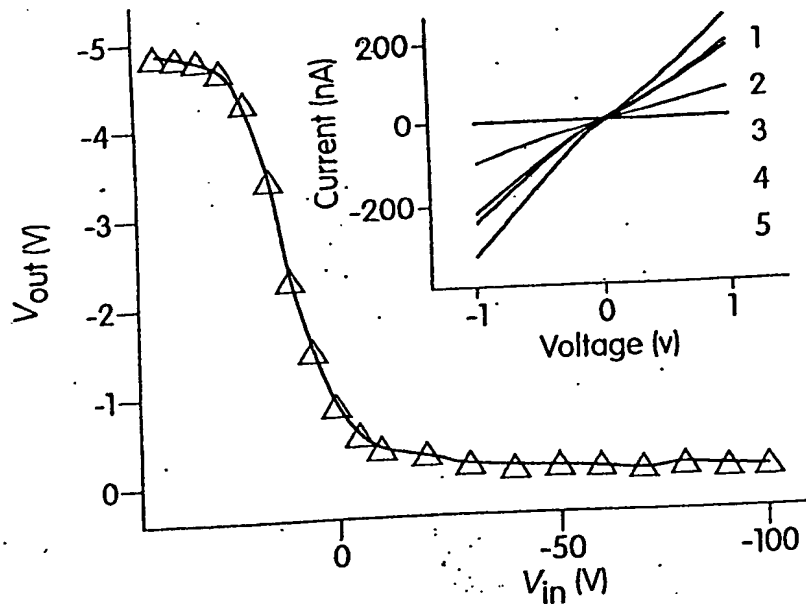


Fig. 29B

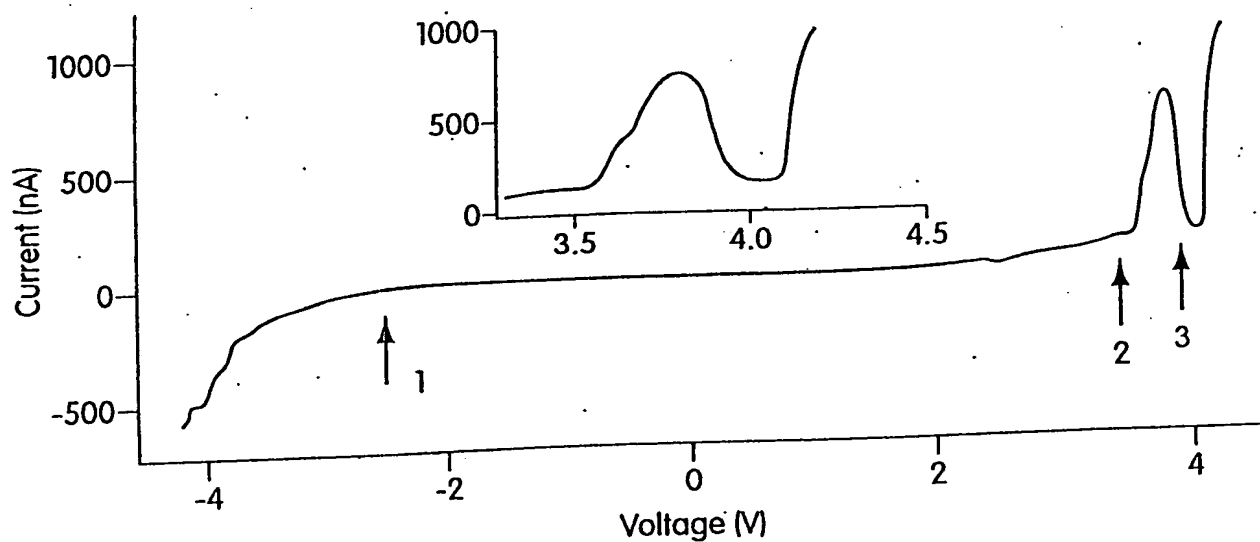


Fig. 29C

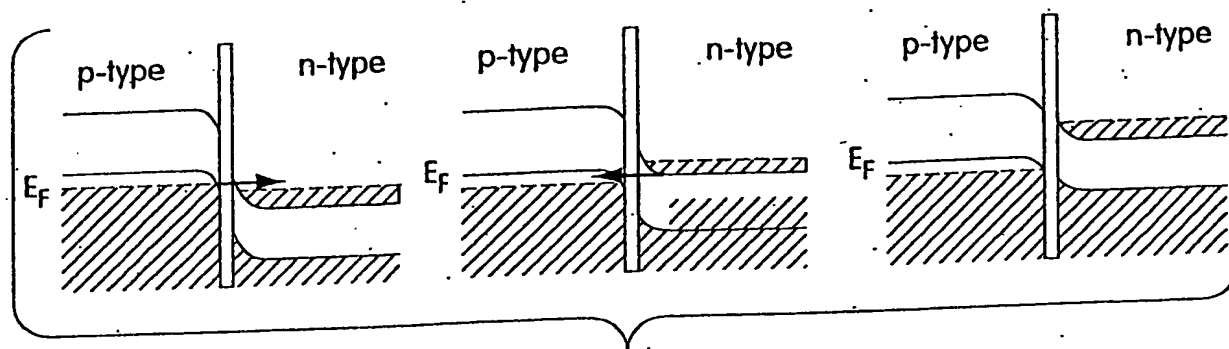
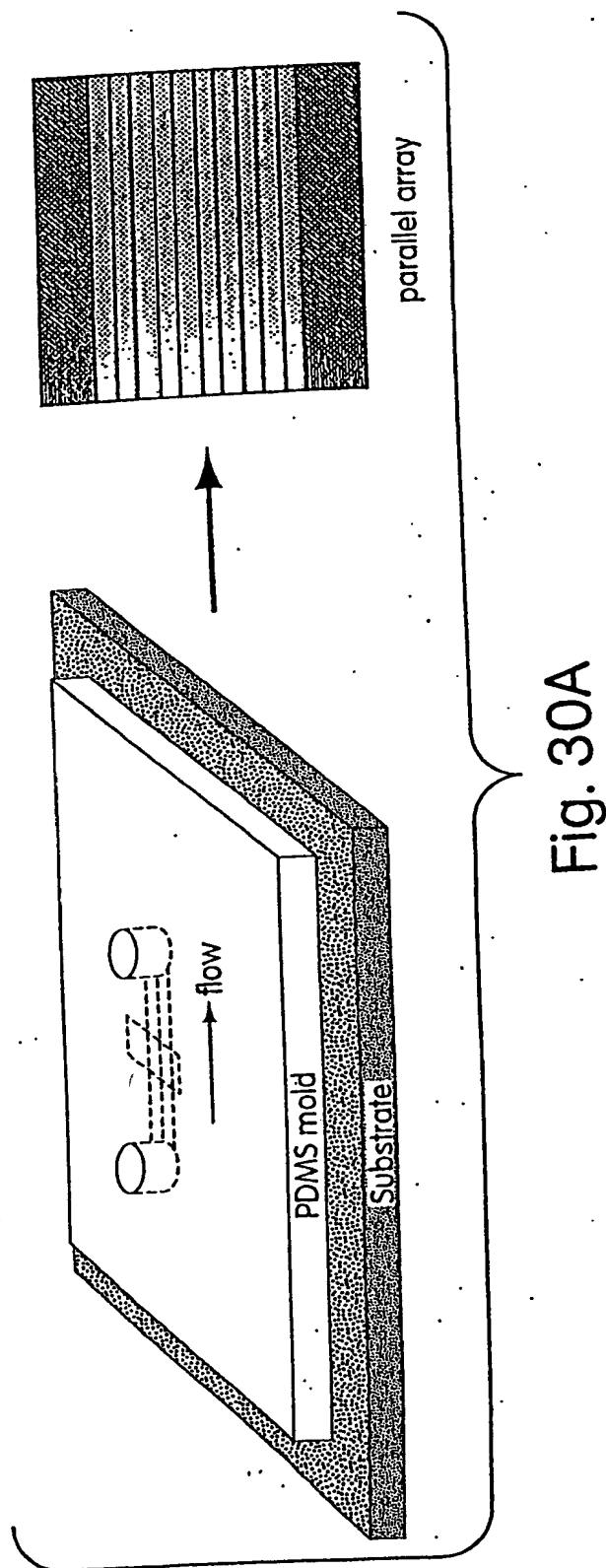


Fig. 29D



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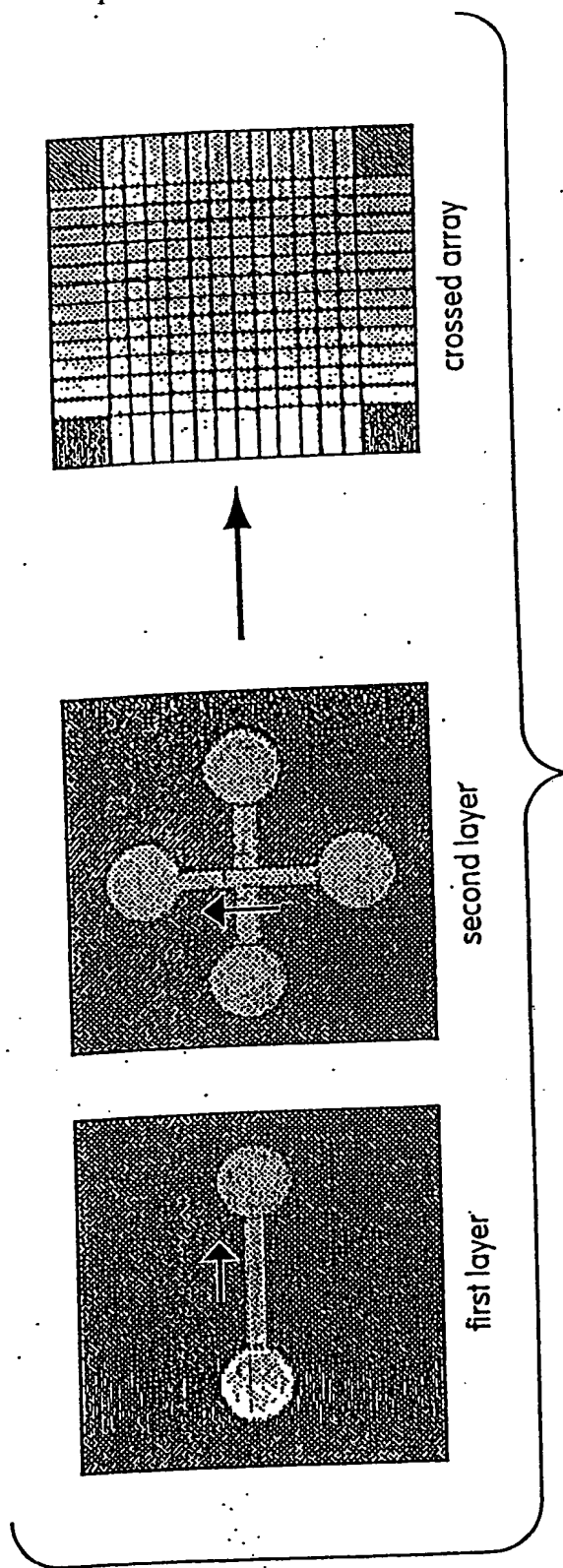


Fig. 30B

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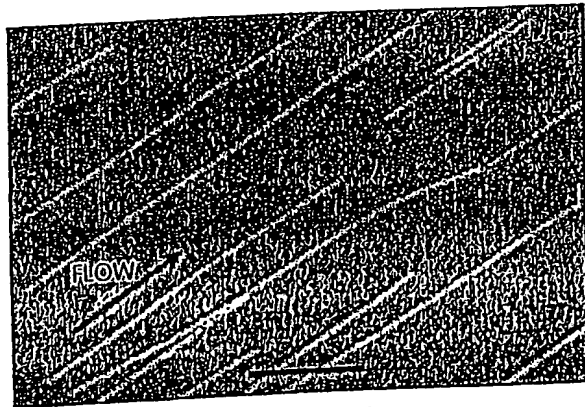


Fig. 31A

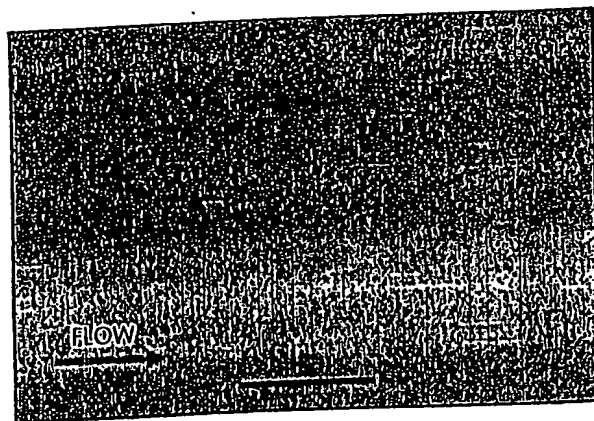


Fig. 31B

H0498.70187US01

NANOSCALE WIRES AND RELATED DEVICES

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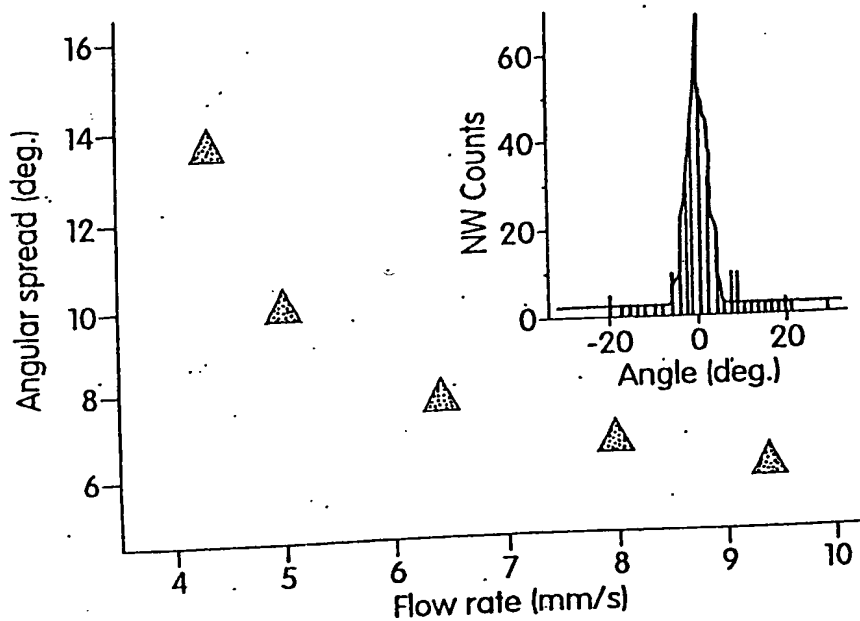


Fig. 31C

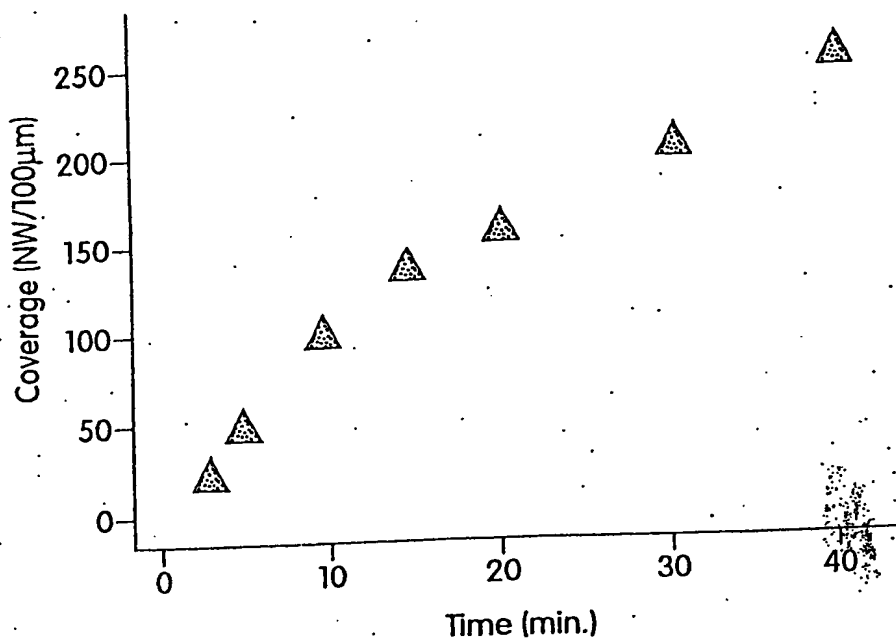


Fig. 31D



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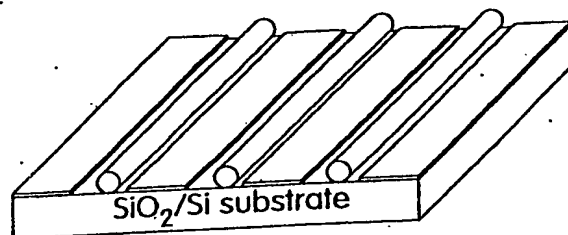


Fig. 32A

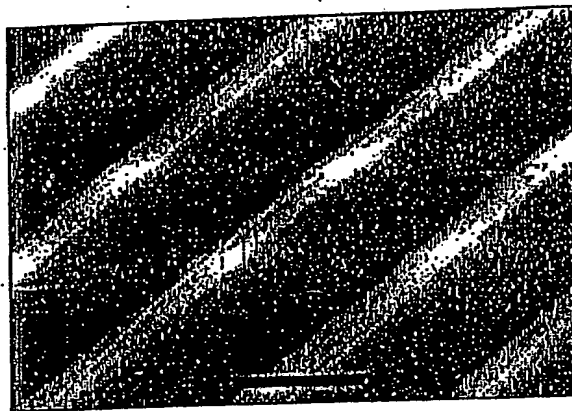


Fig. 32B

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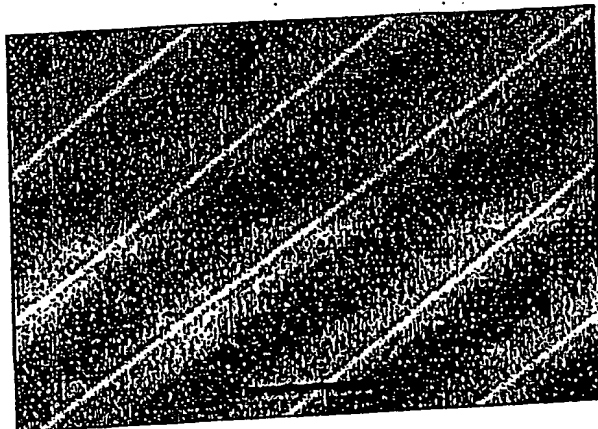


Fig. 32C

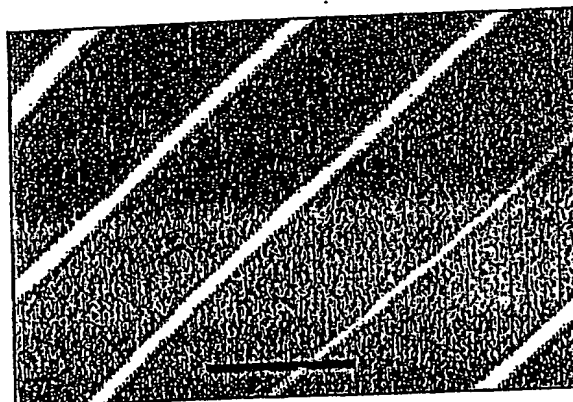


Fig. 32D

H0498.70187US01

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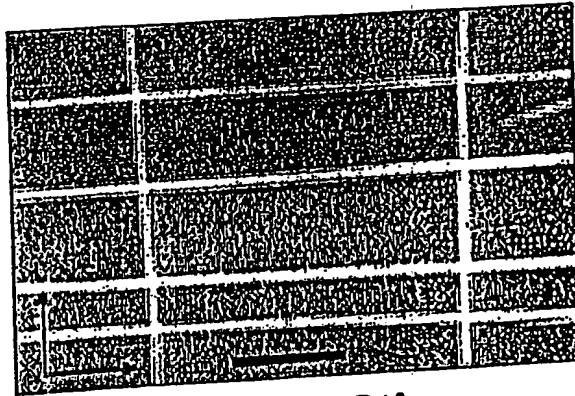


Fig. 33A

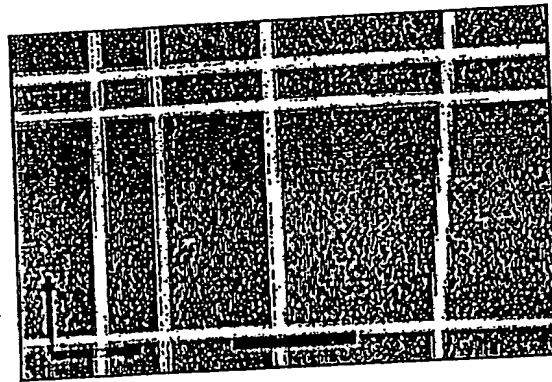


Fig. 33B

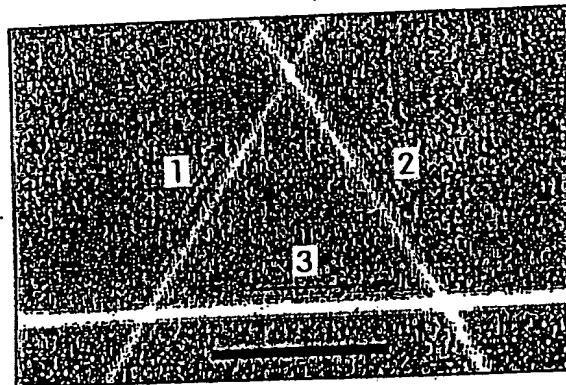


Fig. 33C

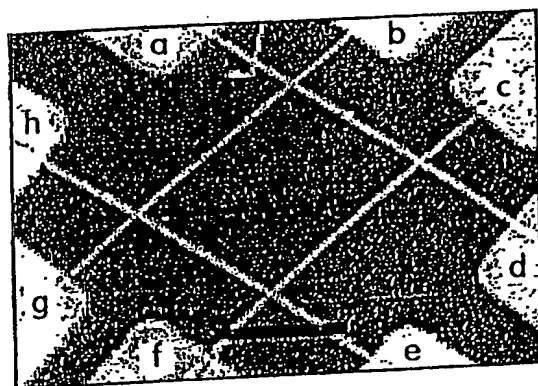


Fig. 33D

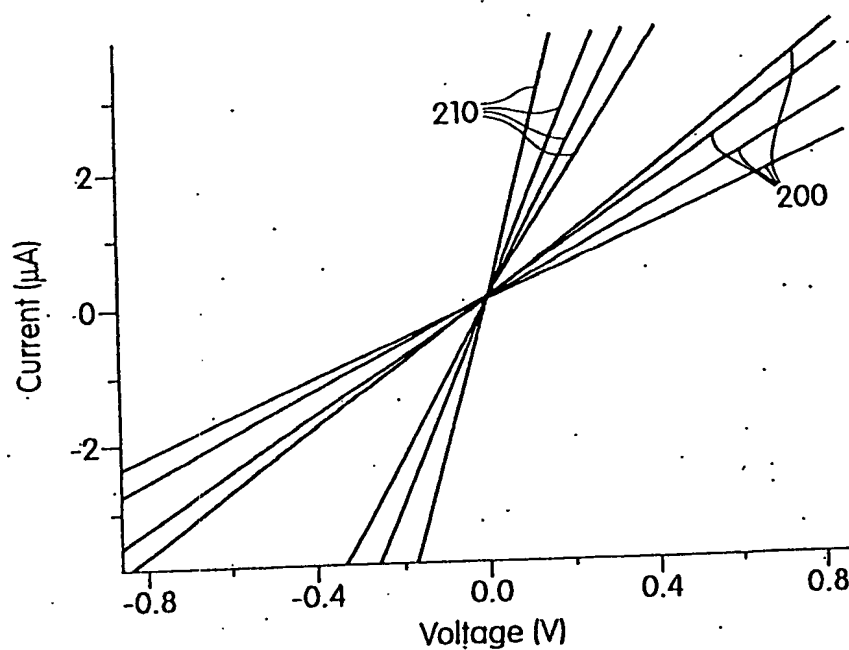


Fig. 33E

Fig. 34

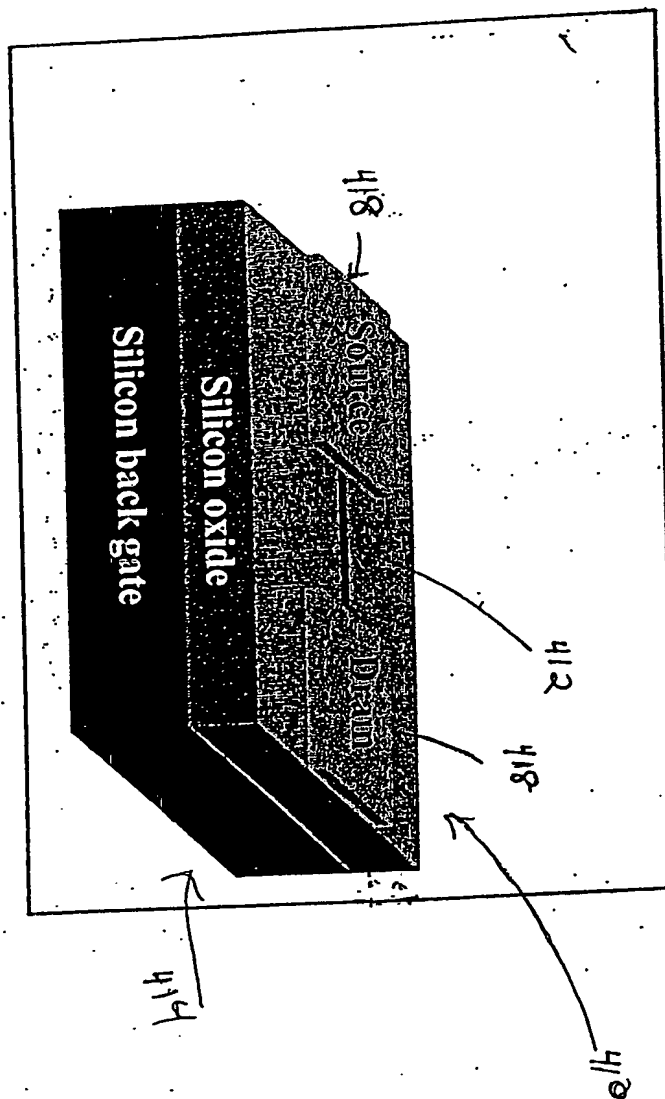




Fig. 35c

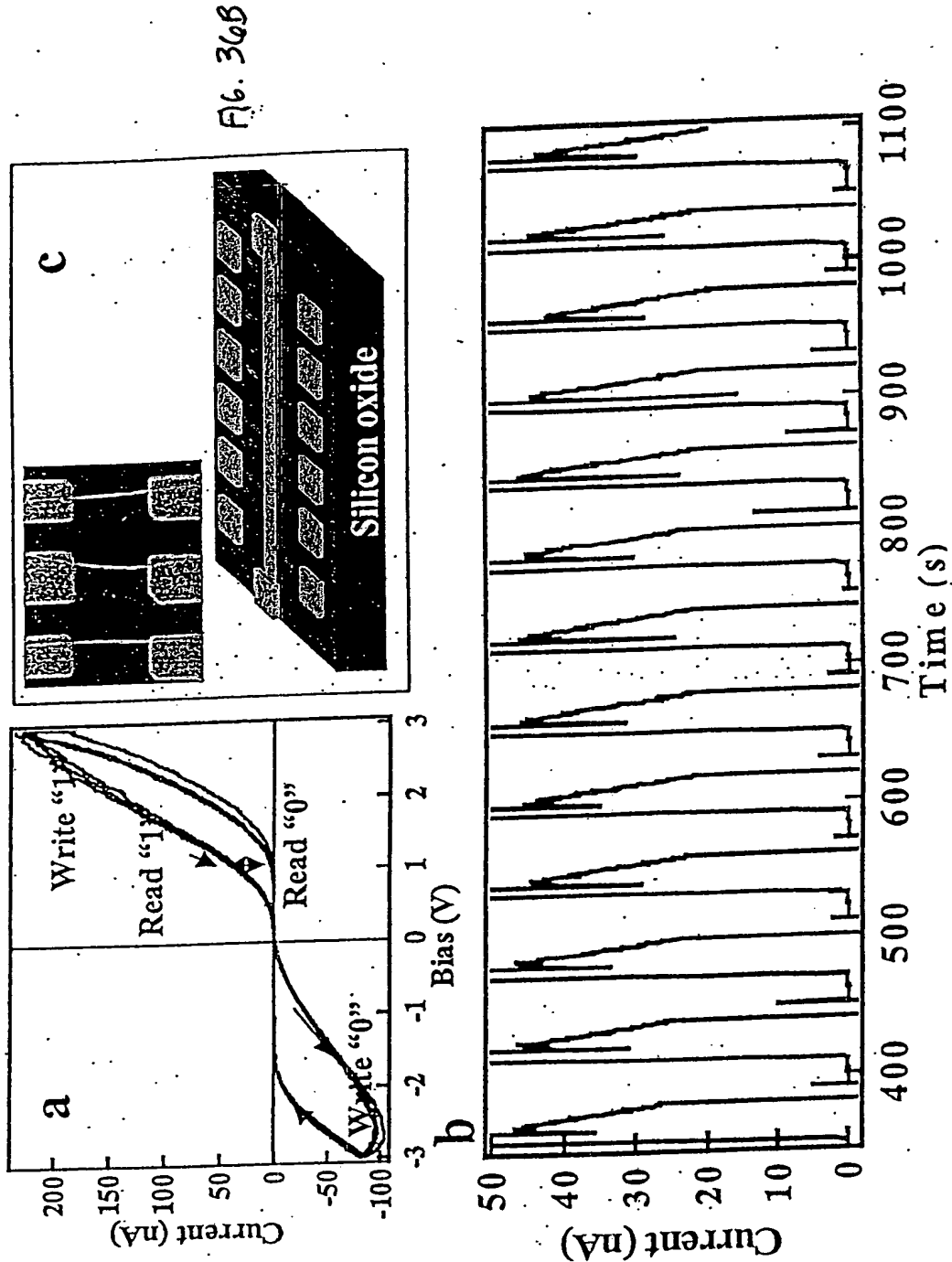
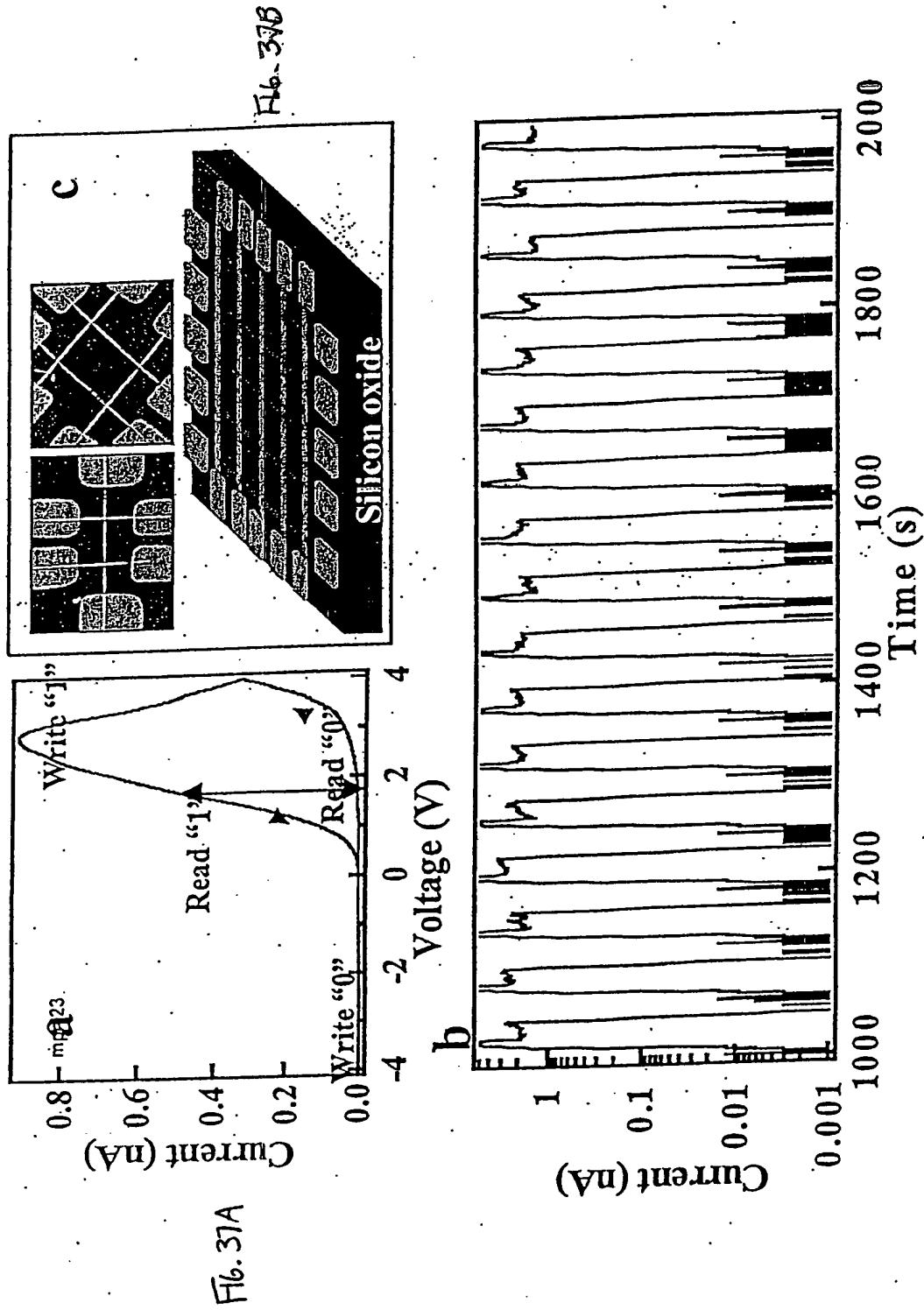


Fig. 36C





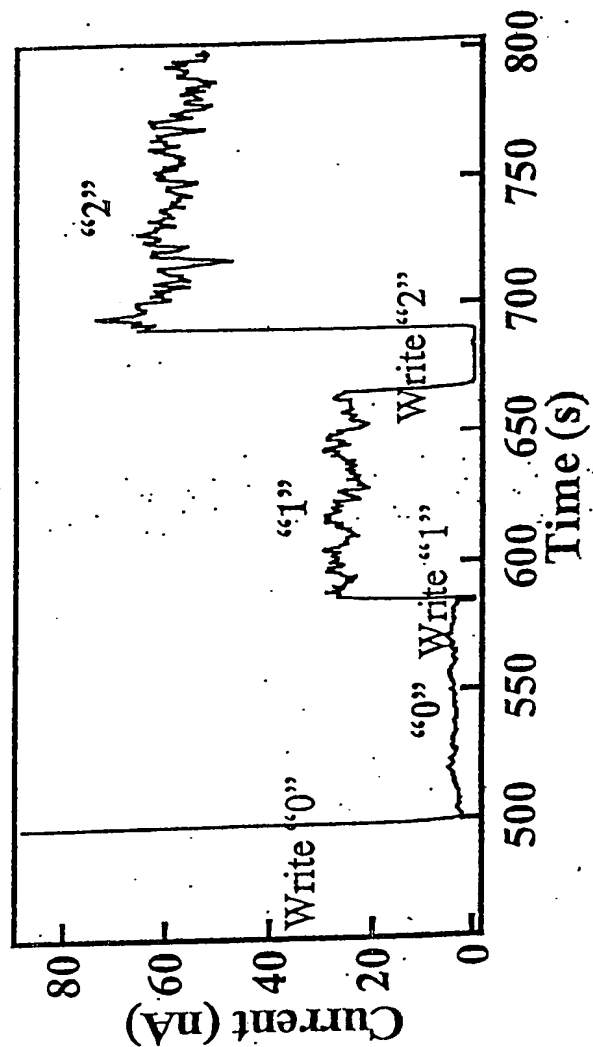


Fig. 38

Fig 39A

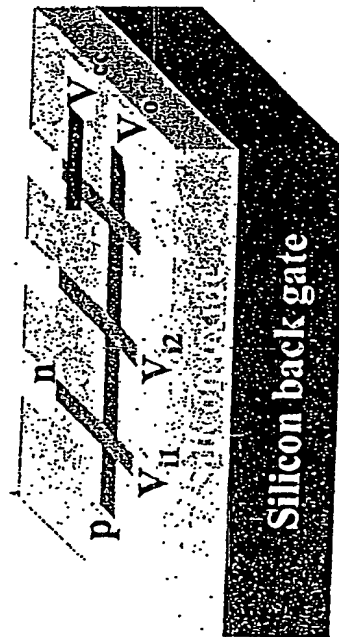


Fig 39B

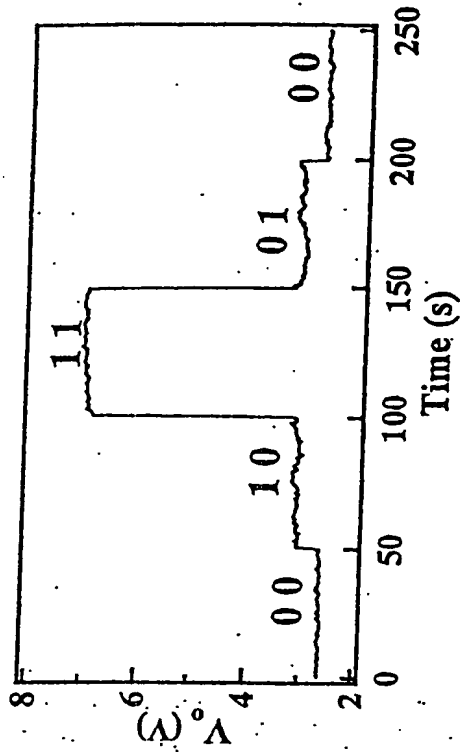


Fig 39C

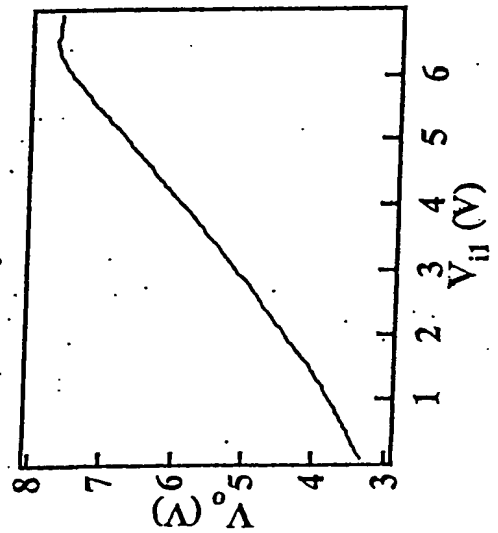


Fig 39D

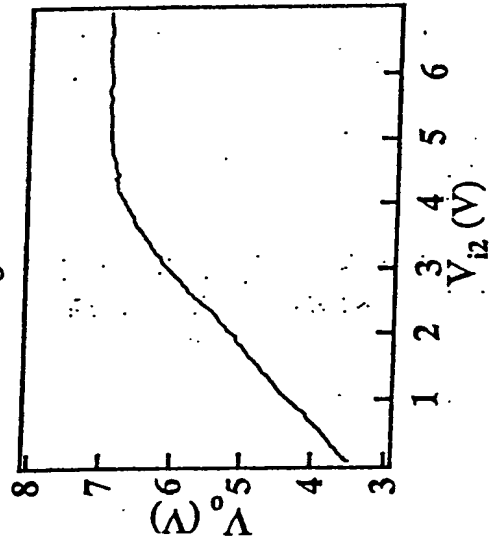


Fig 39E

$V_{11}$	$V_{12}$	$V_0$
0	0	0
0	1	0
1	0	0
1	1	1

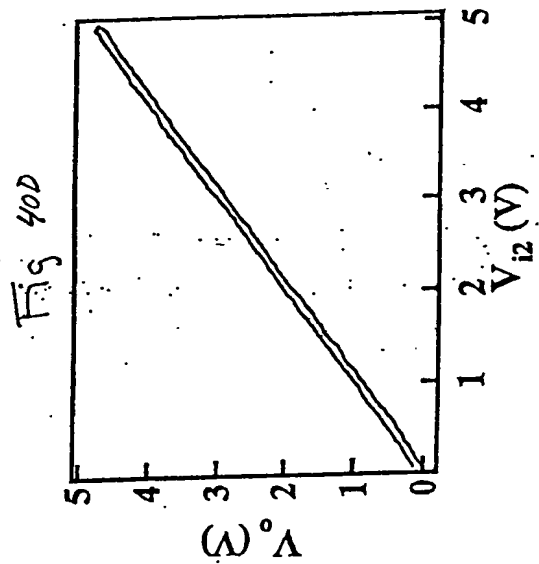
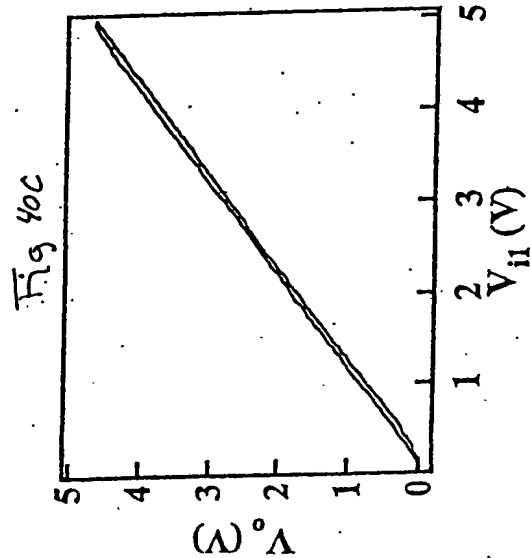
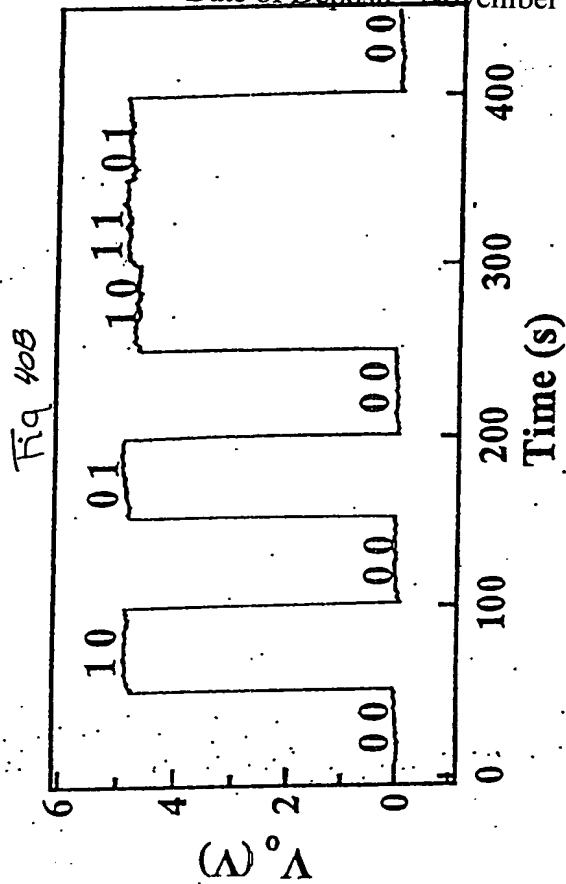
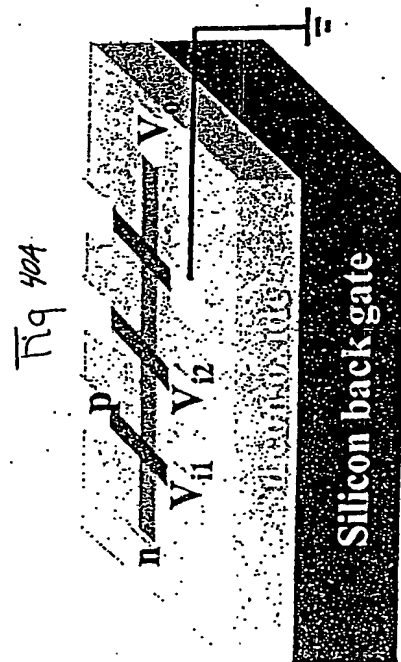
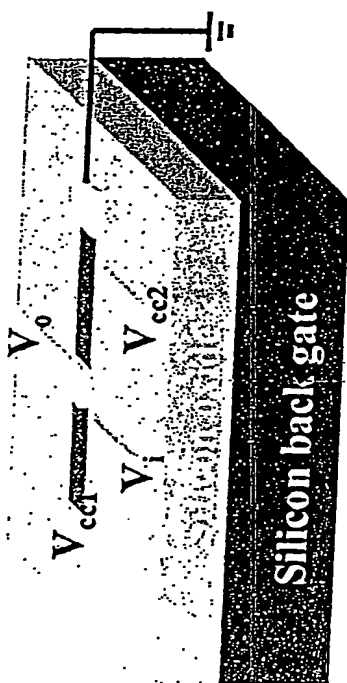


Fig 40E

$V_{i1}$	$V_{i2}$	$V_o$
0	0	0
0	1	1
1	0	1
1	1	1

Fig 4/A



$V_{cc1} = 5\text{ V}$ ,  $V_{cc2} = 2\text{ V}$ ,  $V_i = 0, 5\text{ V}$

Fig 4/B

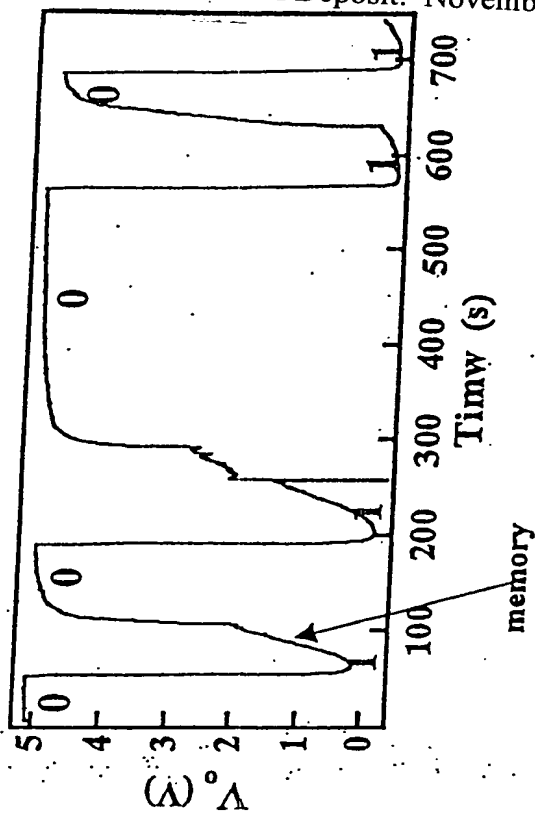


Fig 4/C

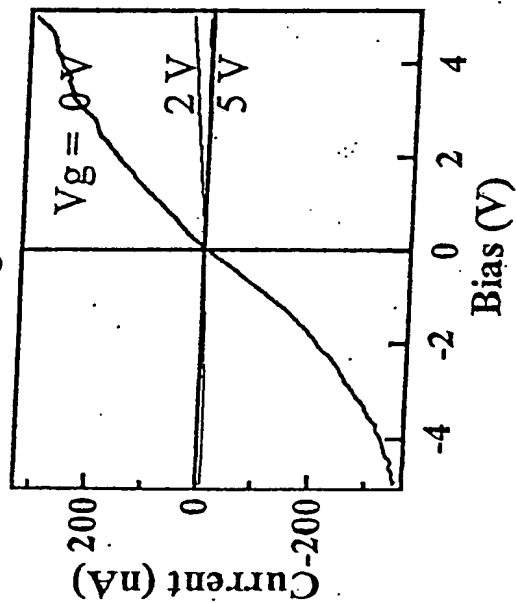


Fig 4/D

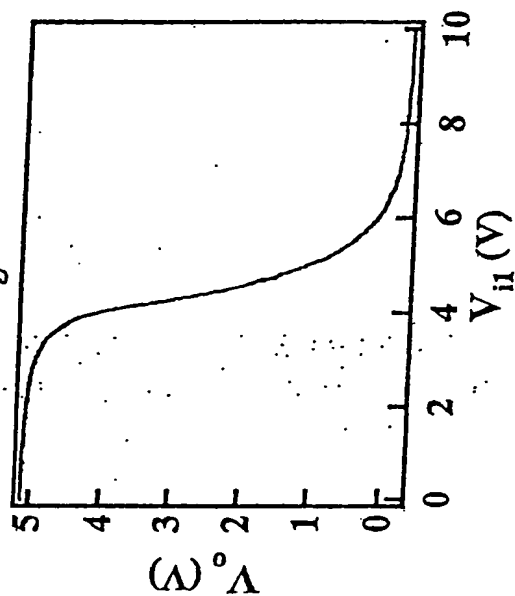


Fig 4/E

$V_i$	$V_o$
0	0
1	0

Fig 42A

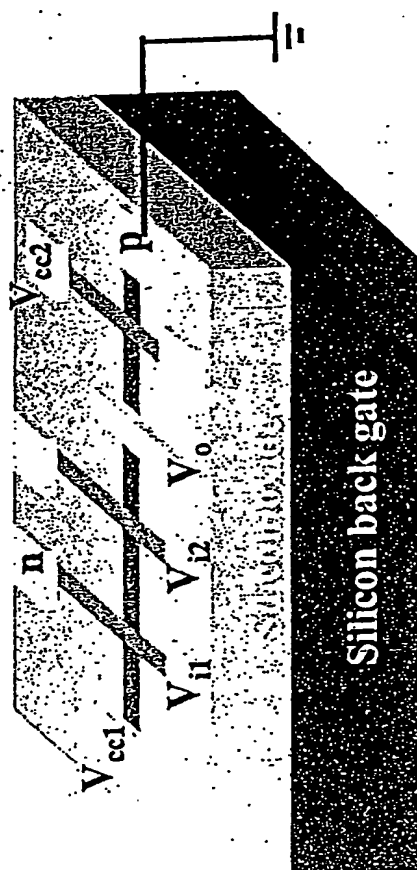


Fig 42B

$V_{i1}$	$V_{i2}$	$V_o$
0	0	1
0	1	0
1	0	0
1	1	0

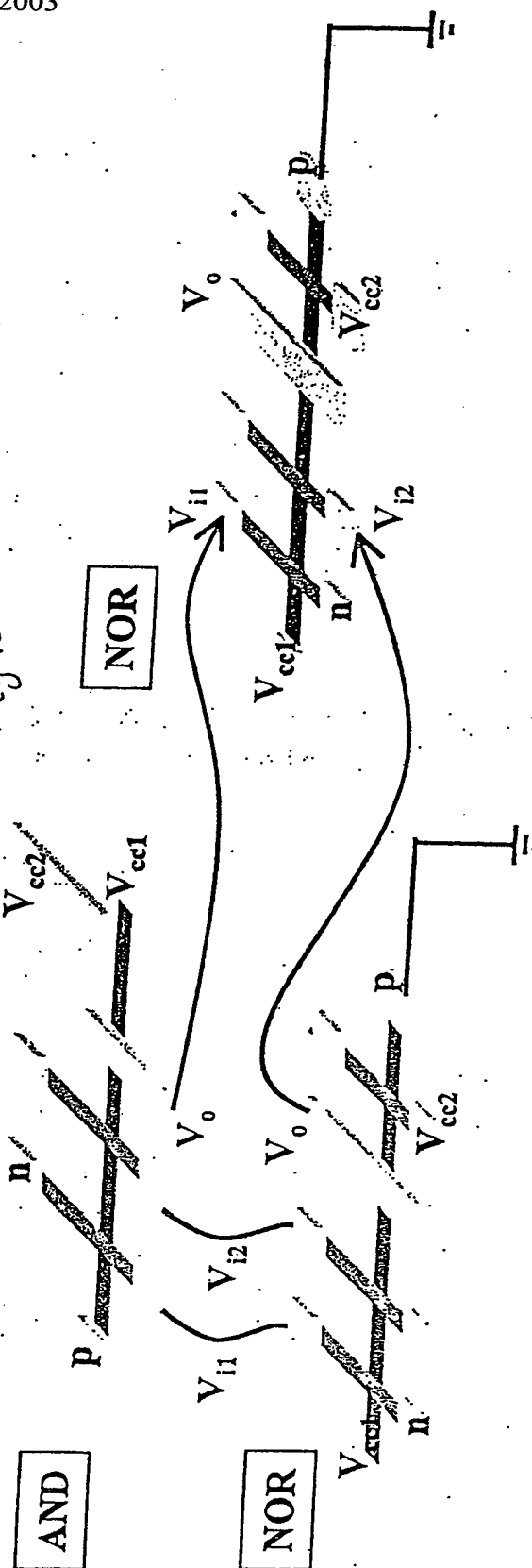
Fig. 43A

$V_{i1}$	$V_{i2}$	NOR AND $V_o$	$V_o$
0	0	1	0
0	1	0	1
1	0	0	1
1	1	0	0

INPUT TO NOR



Fig 43B



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Fig. 44A

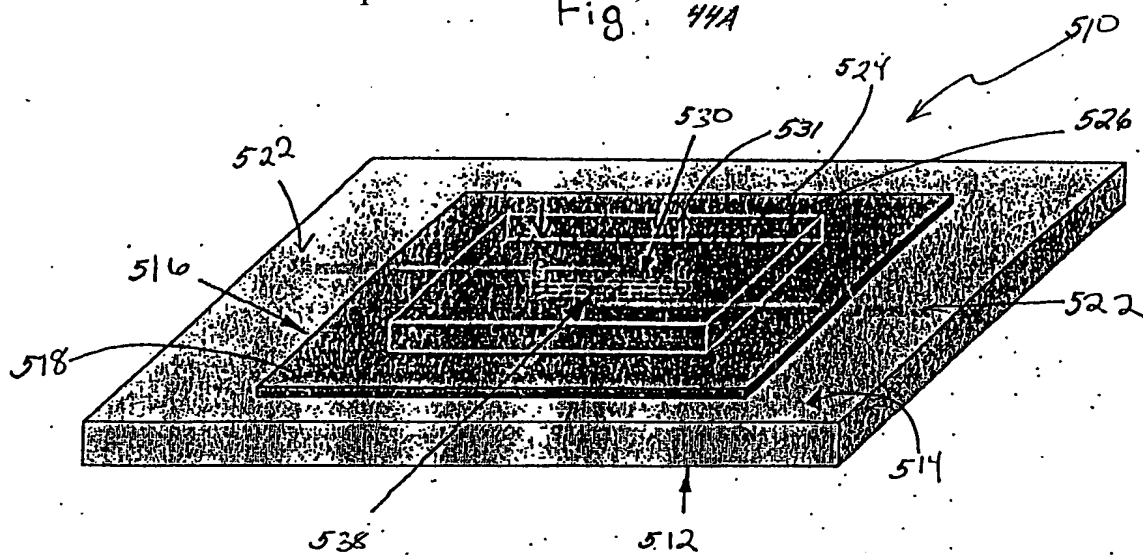
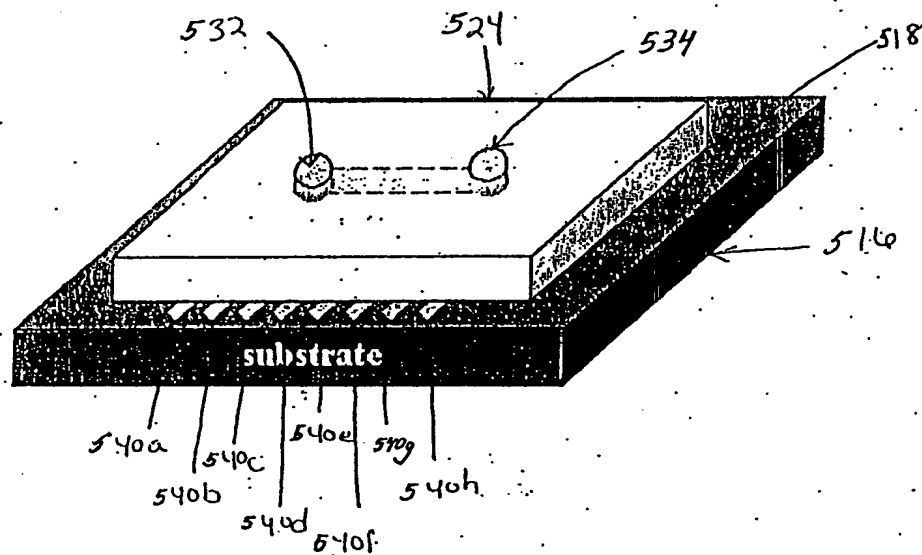


Fig. 44B



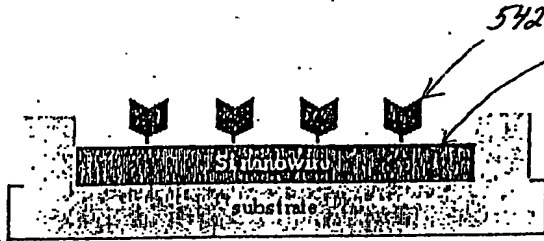


Figure 45A

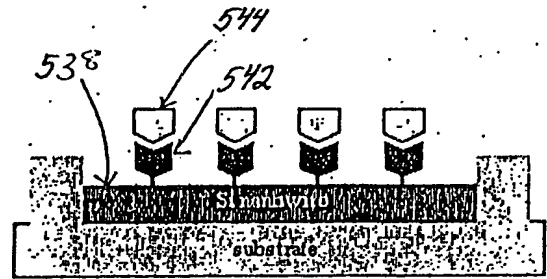
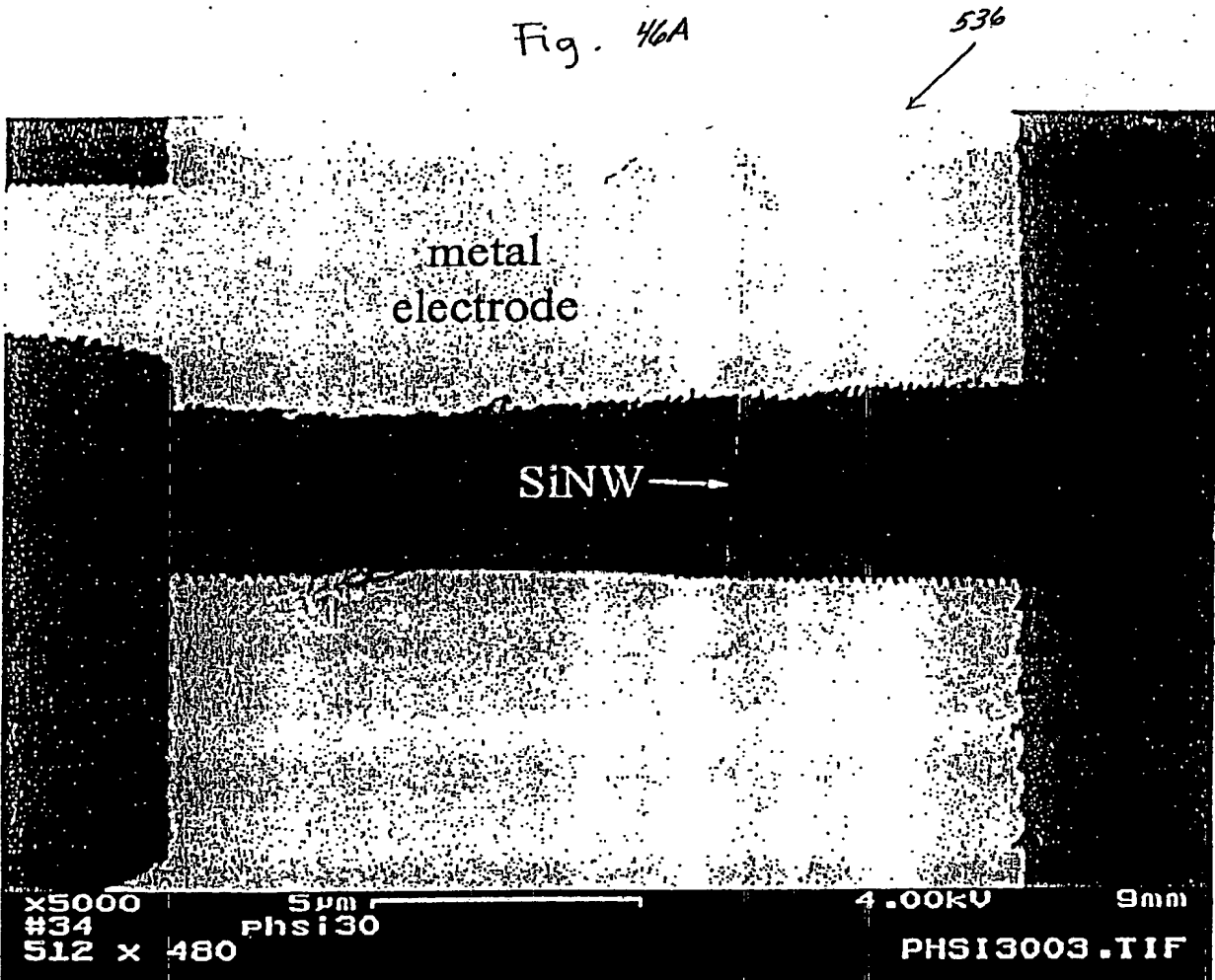


Figure 45B





H0498.70187US01

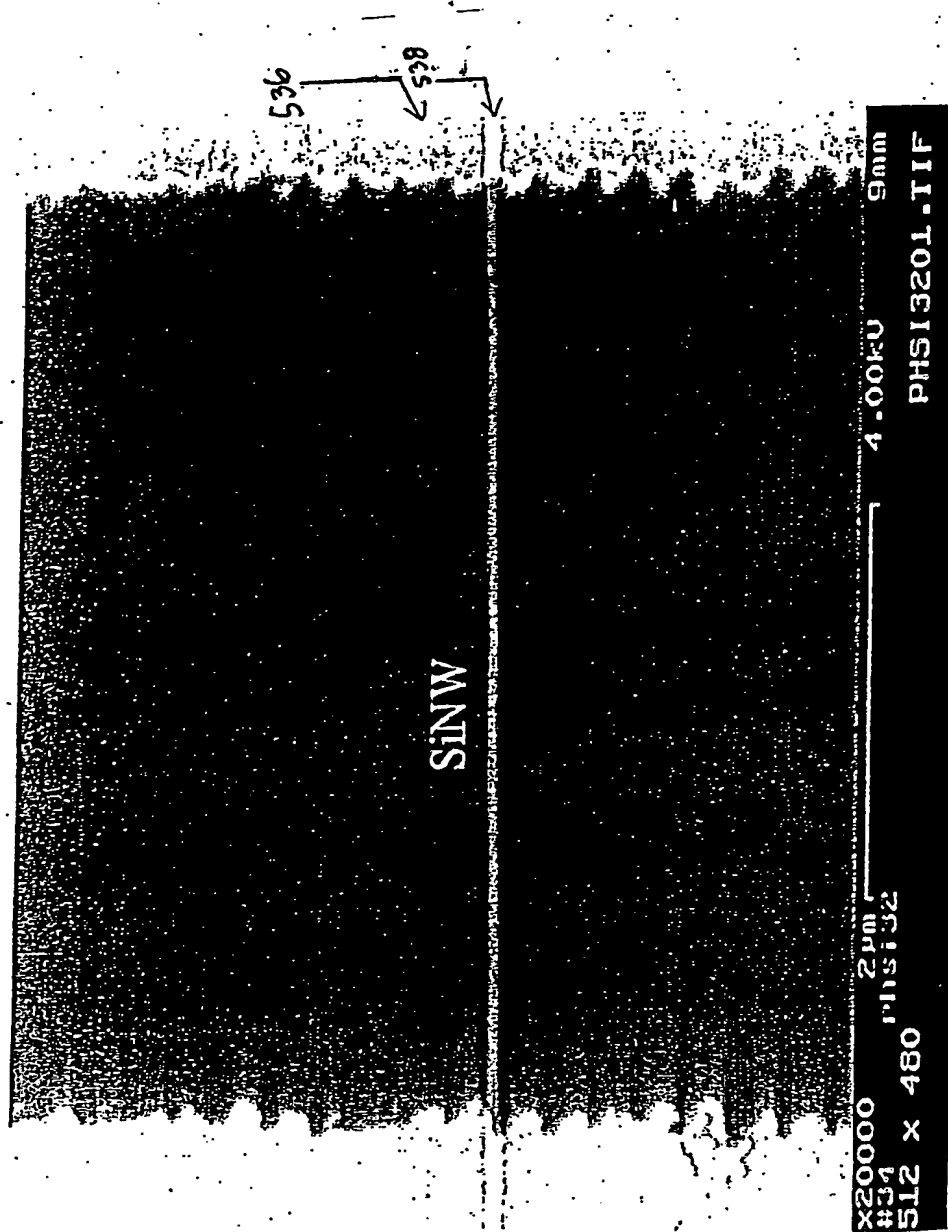
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Fig. 46B



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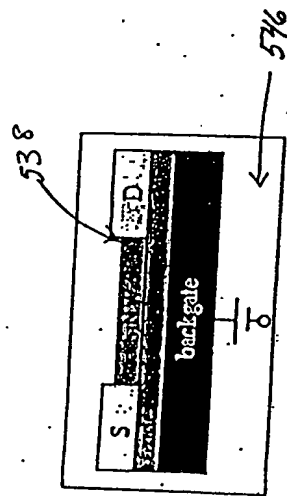
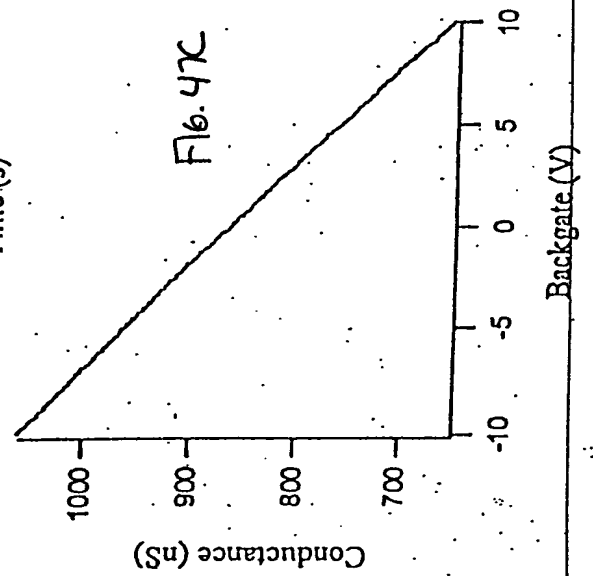
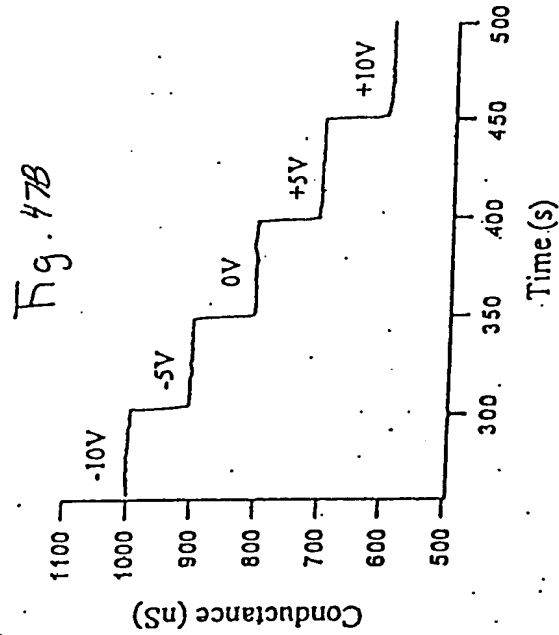


Figure 47A

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FIG. 48A

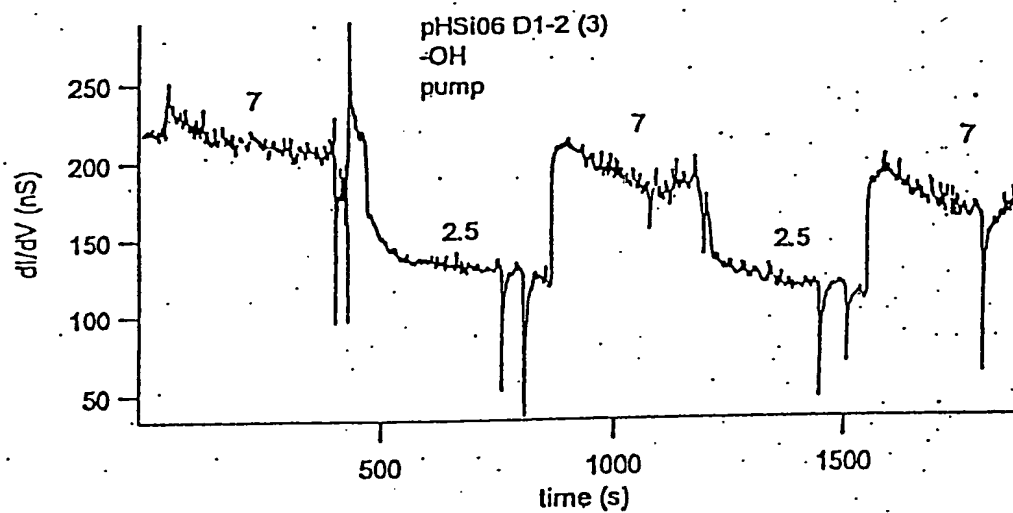


FIG. 48B

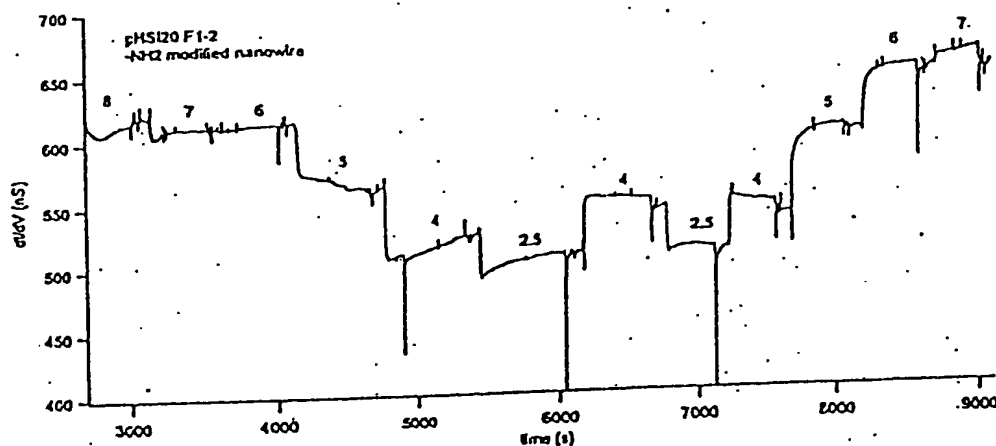


FIG. 49

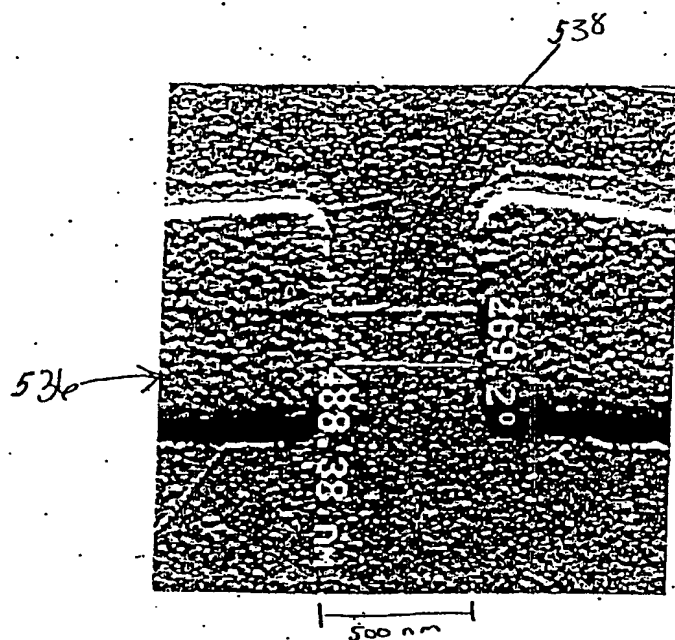
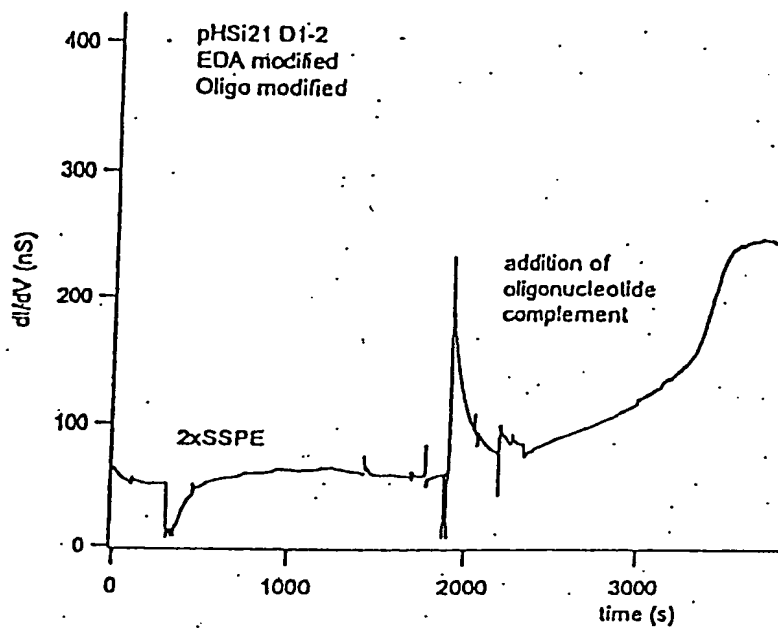


Fig. 50

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FIG. 51A

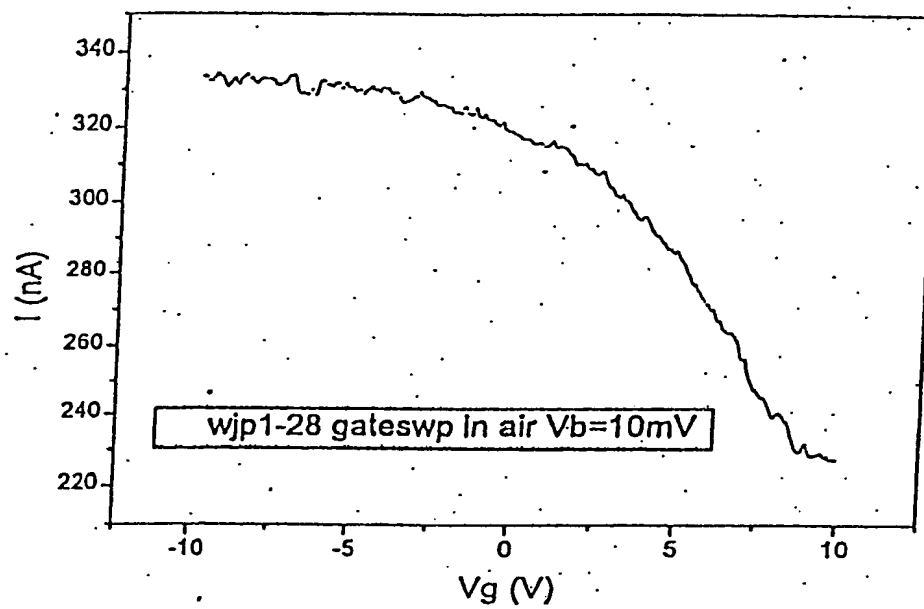


FIG. 5/B

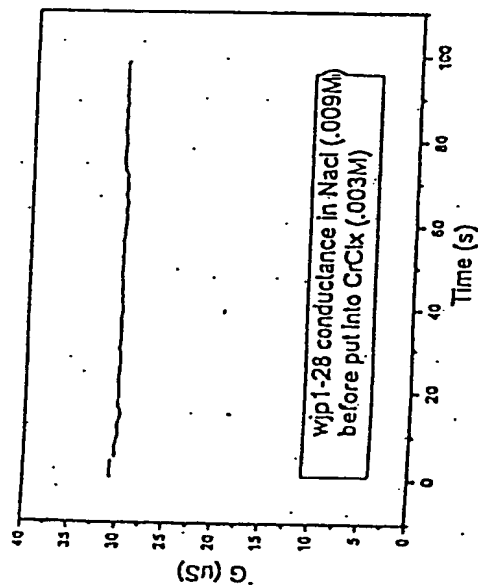
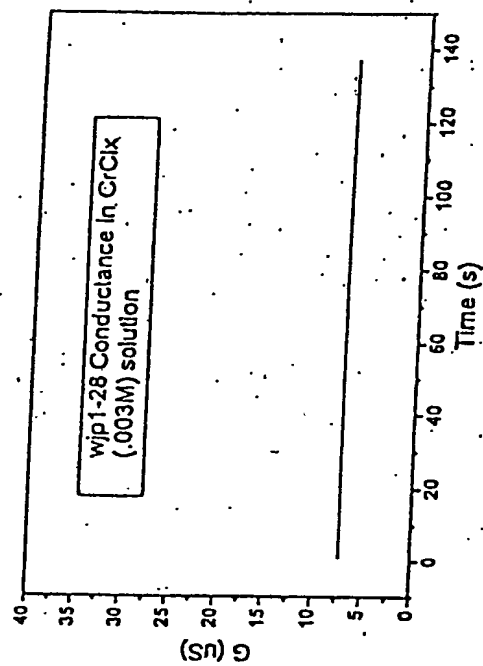


FIG. 5/C



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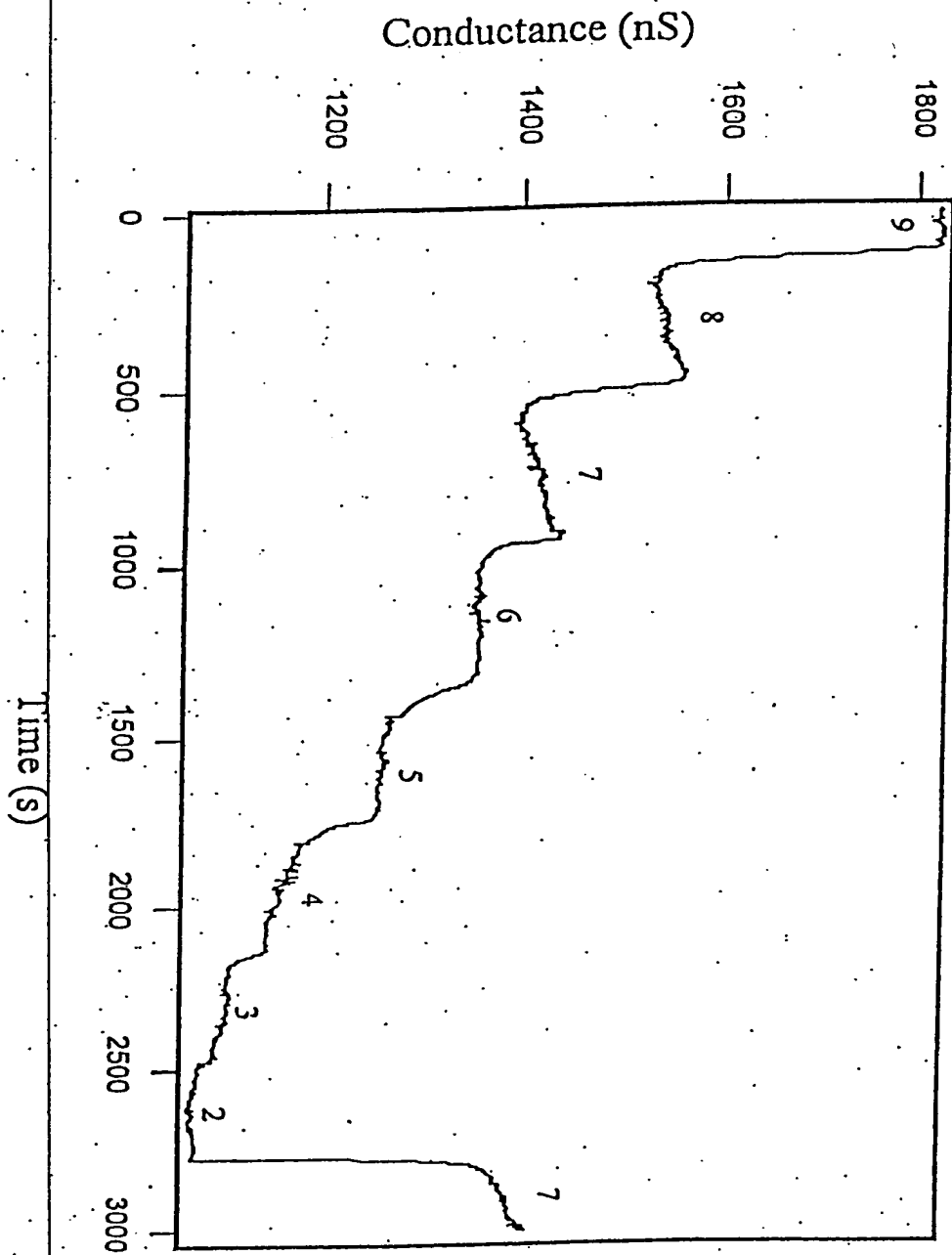


Fig 52A

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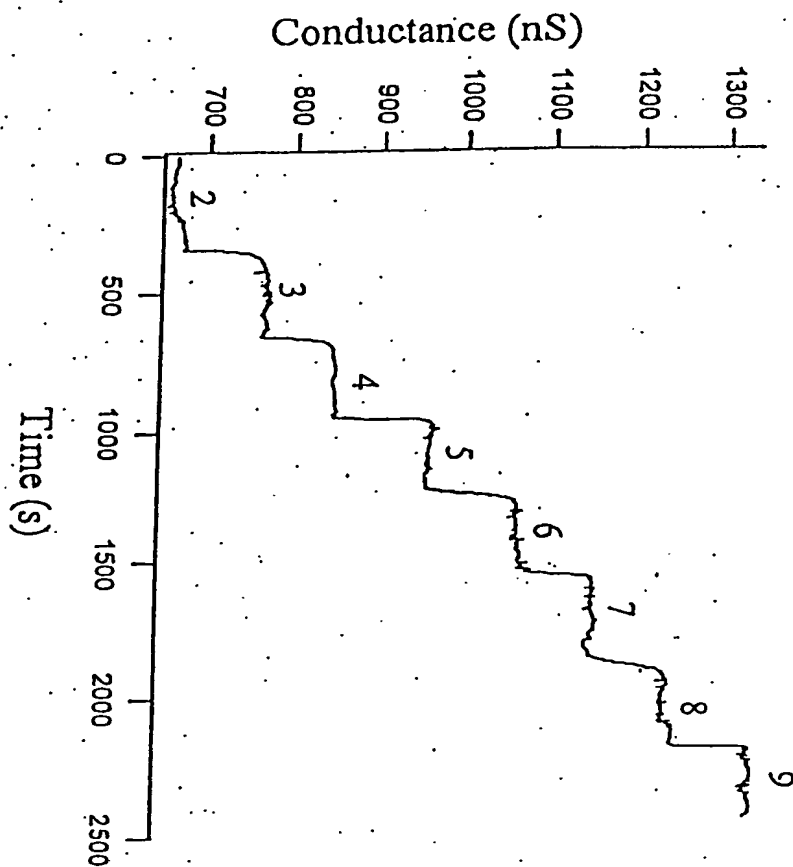


Fig 5a8



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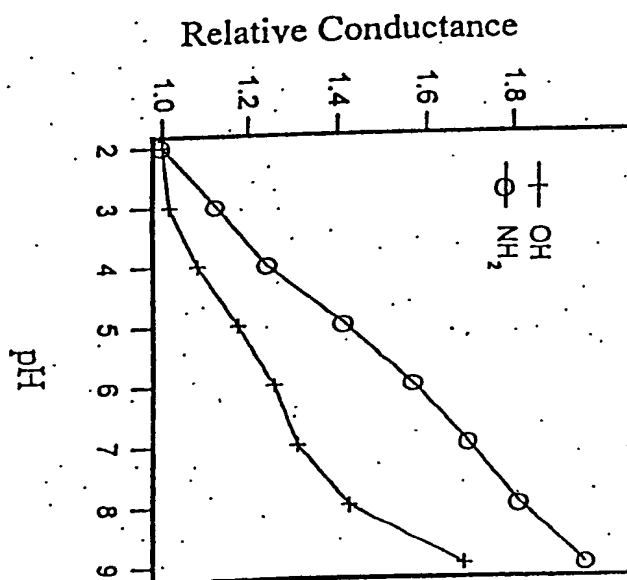


Fig. 5a

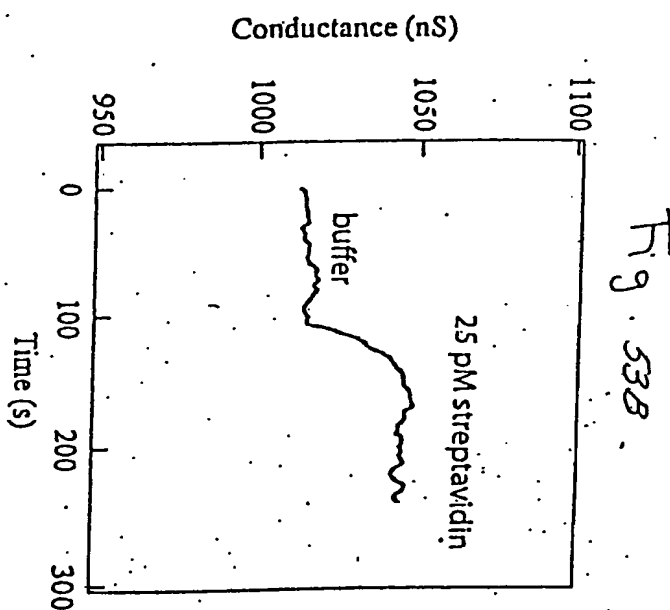
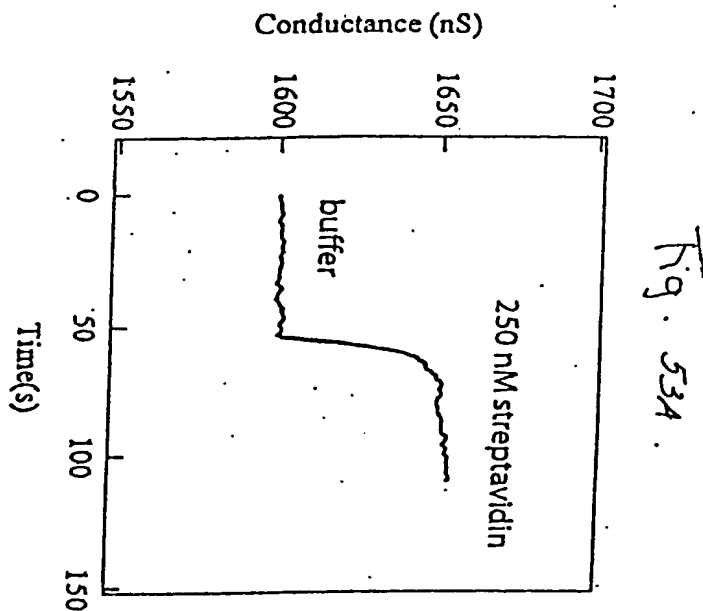
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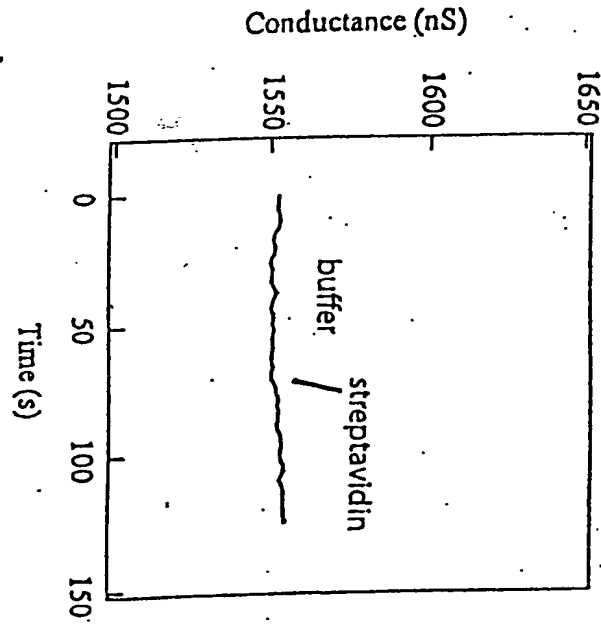


Fig. 53c

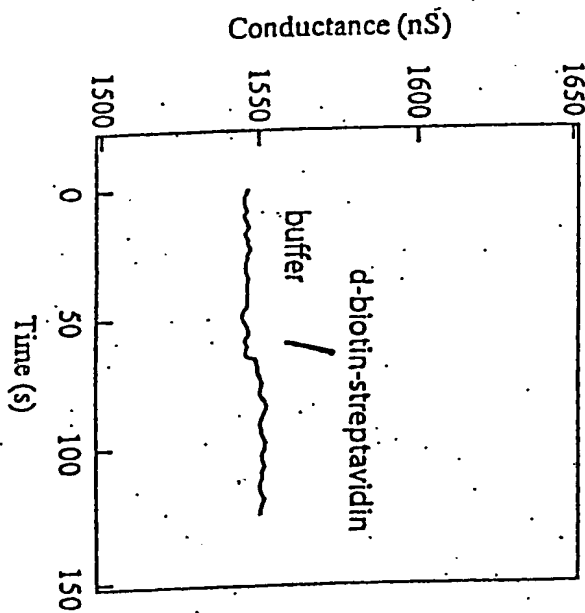
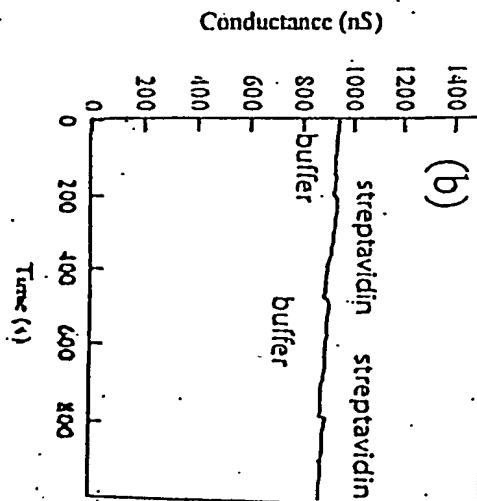
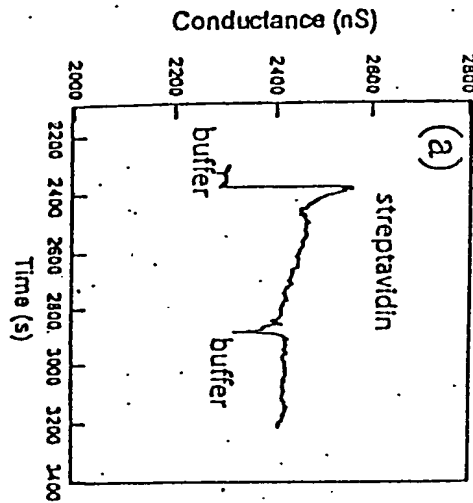


Fig. 53d

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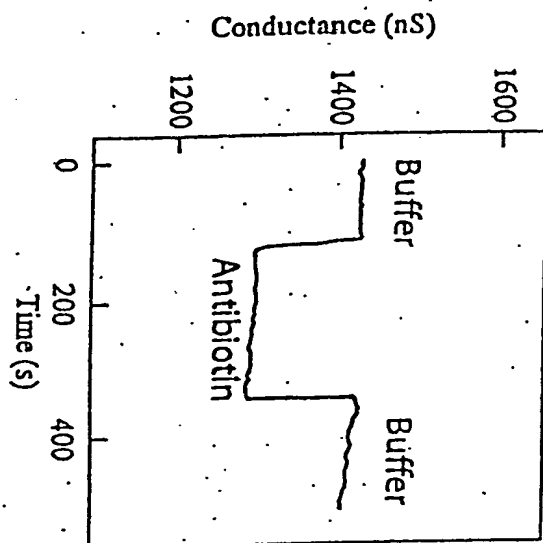


Fig. 54A

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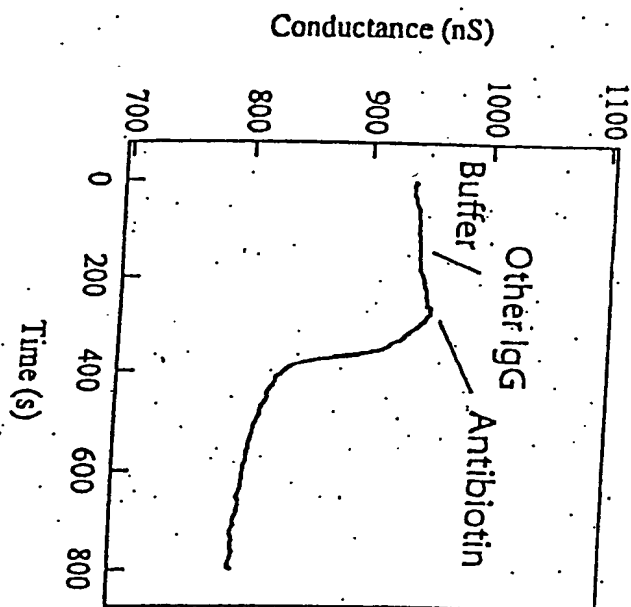
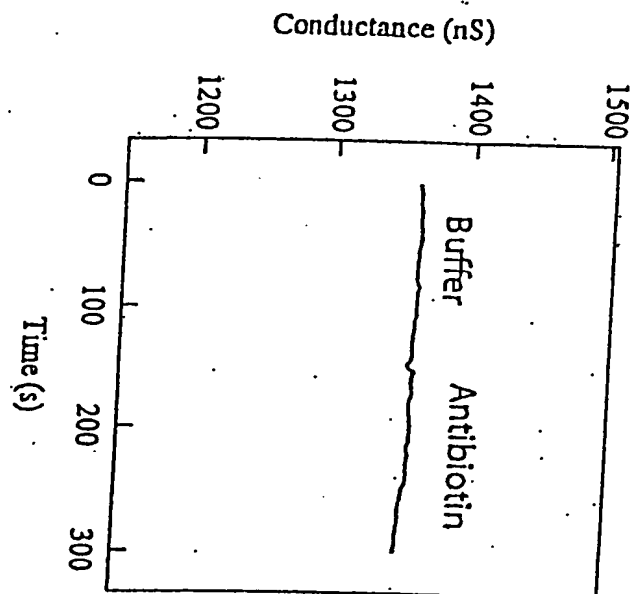


Fig 55A

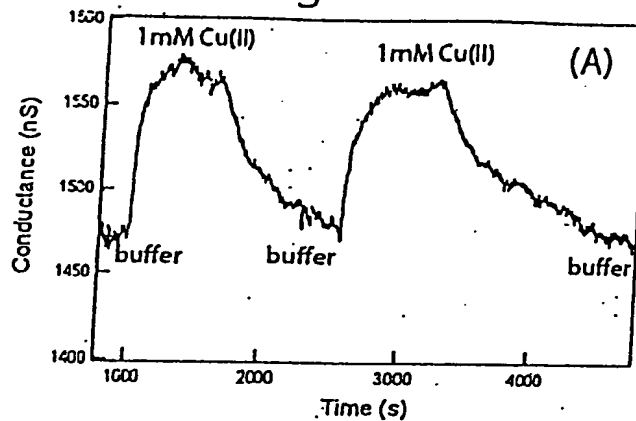


Fig. 55B

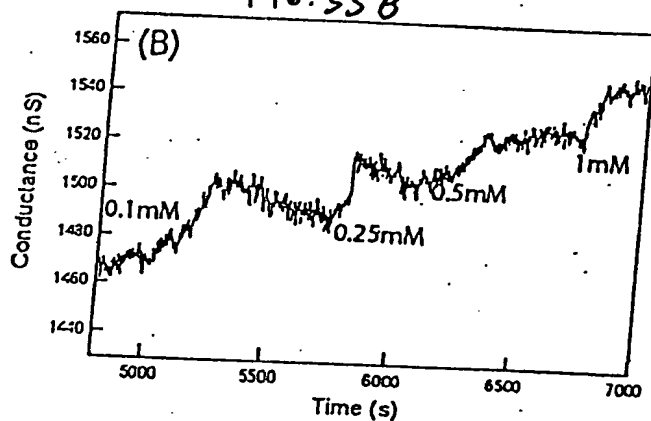


Fig 55C

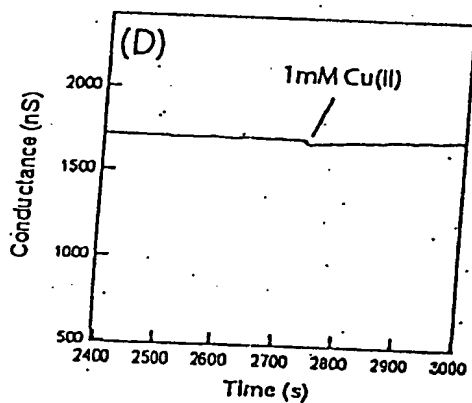
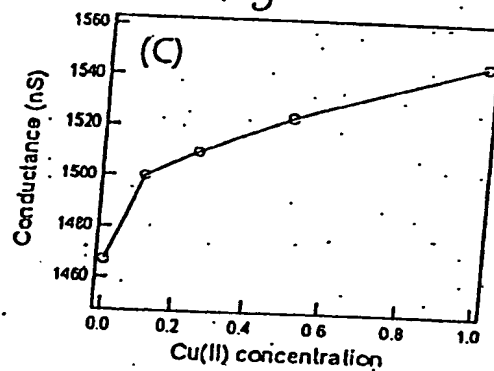


Fig. 55D

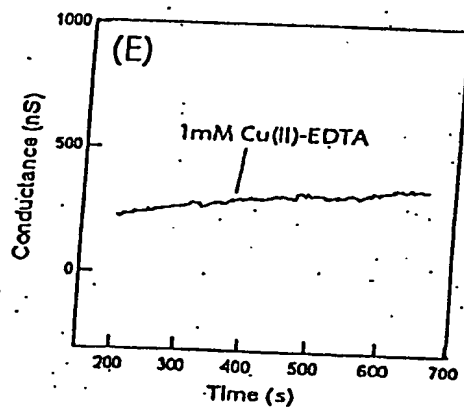


Fig. 55E

FIG. 56A

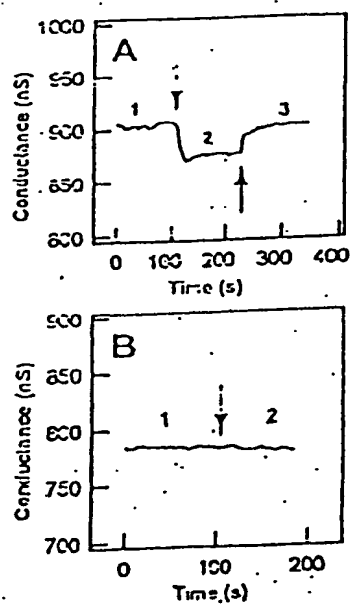


Fig 56B



# Sensitivity dependent on doping and size of nanowires

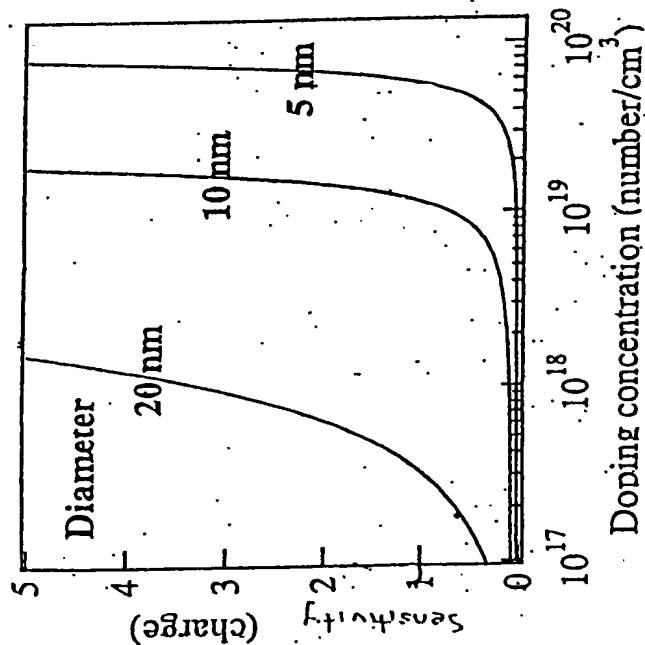


Fig 574

# Threshold doping density for single charge detection

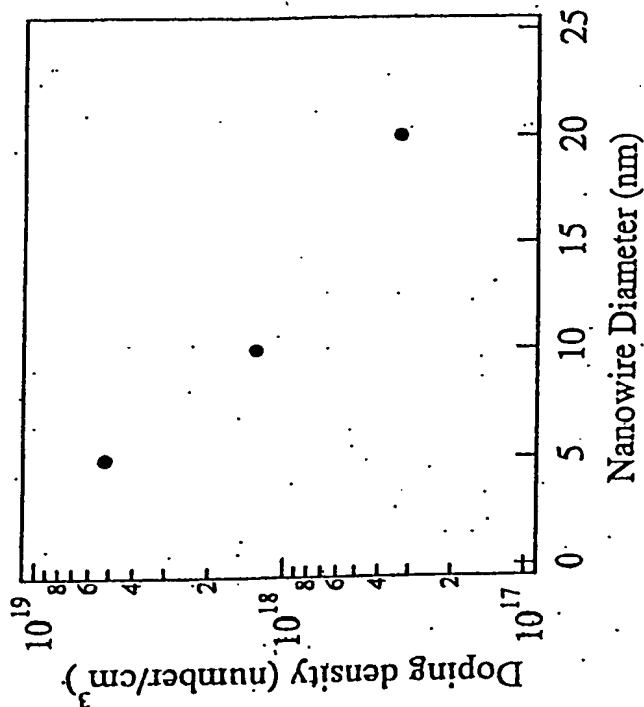


Fig 578

# InP pH Sensor

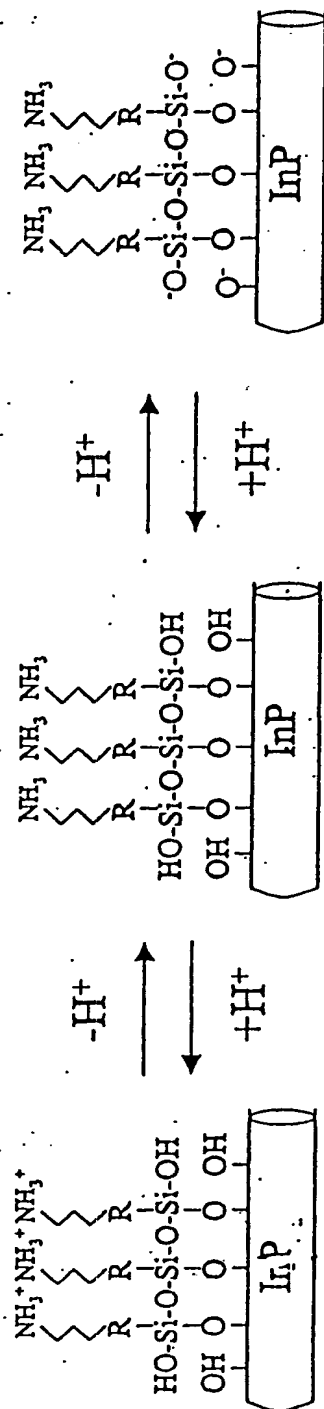


Fig 58A

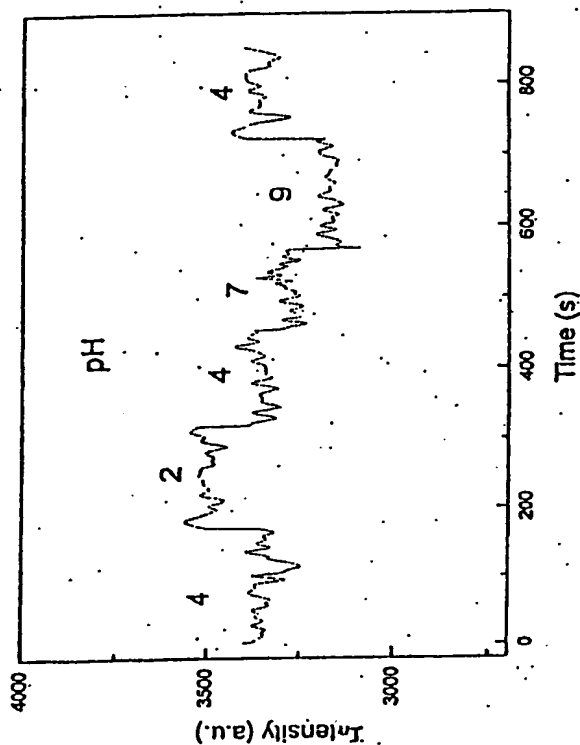


Fig. 58B

Fig. 59a

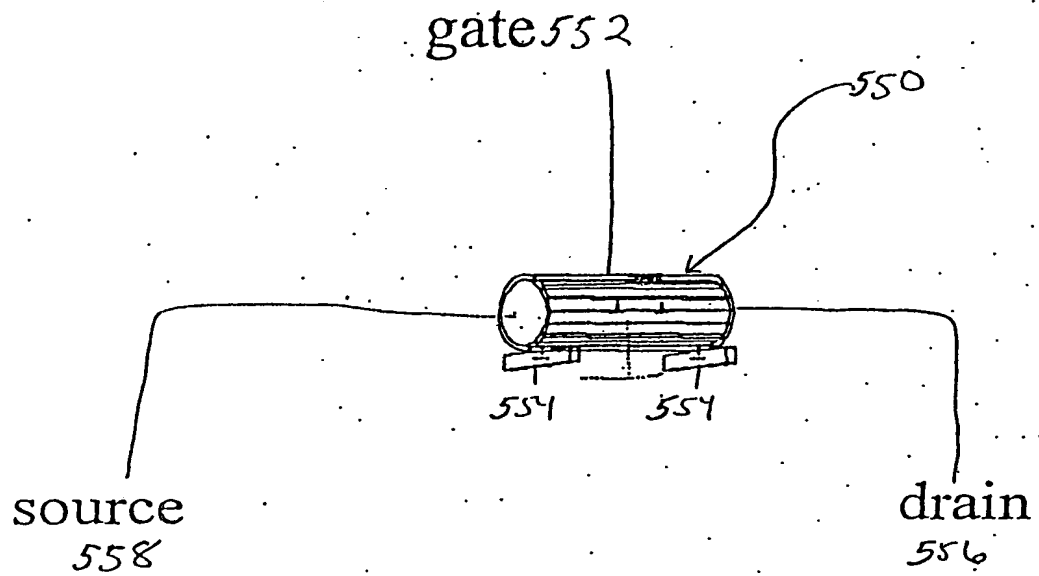


Fig. 59 b

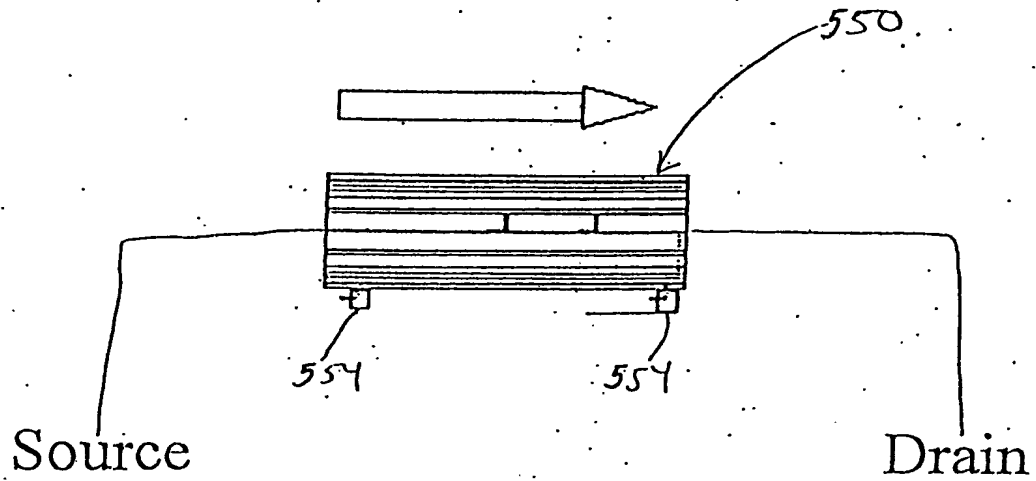


Fig. 59 c

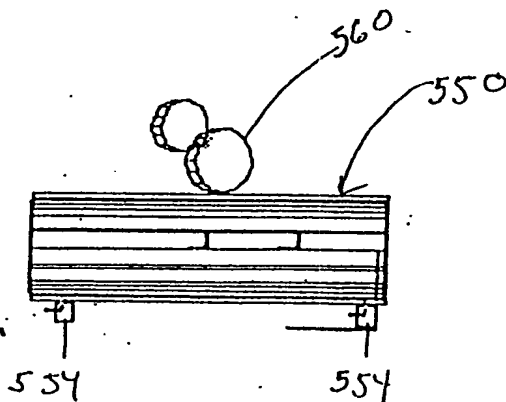
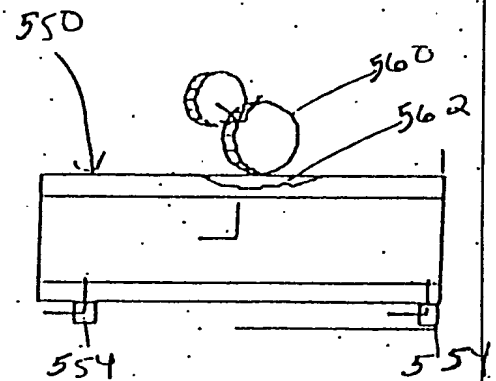


Fig. 59 d



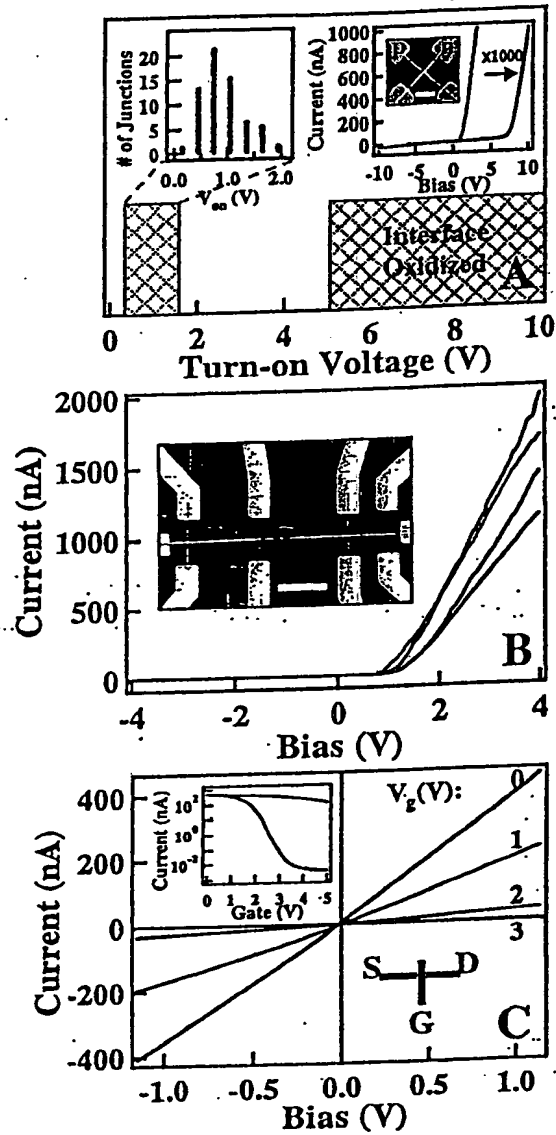


Figure 60

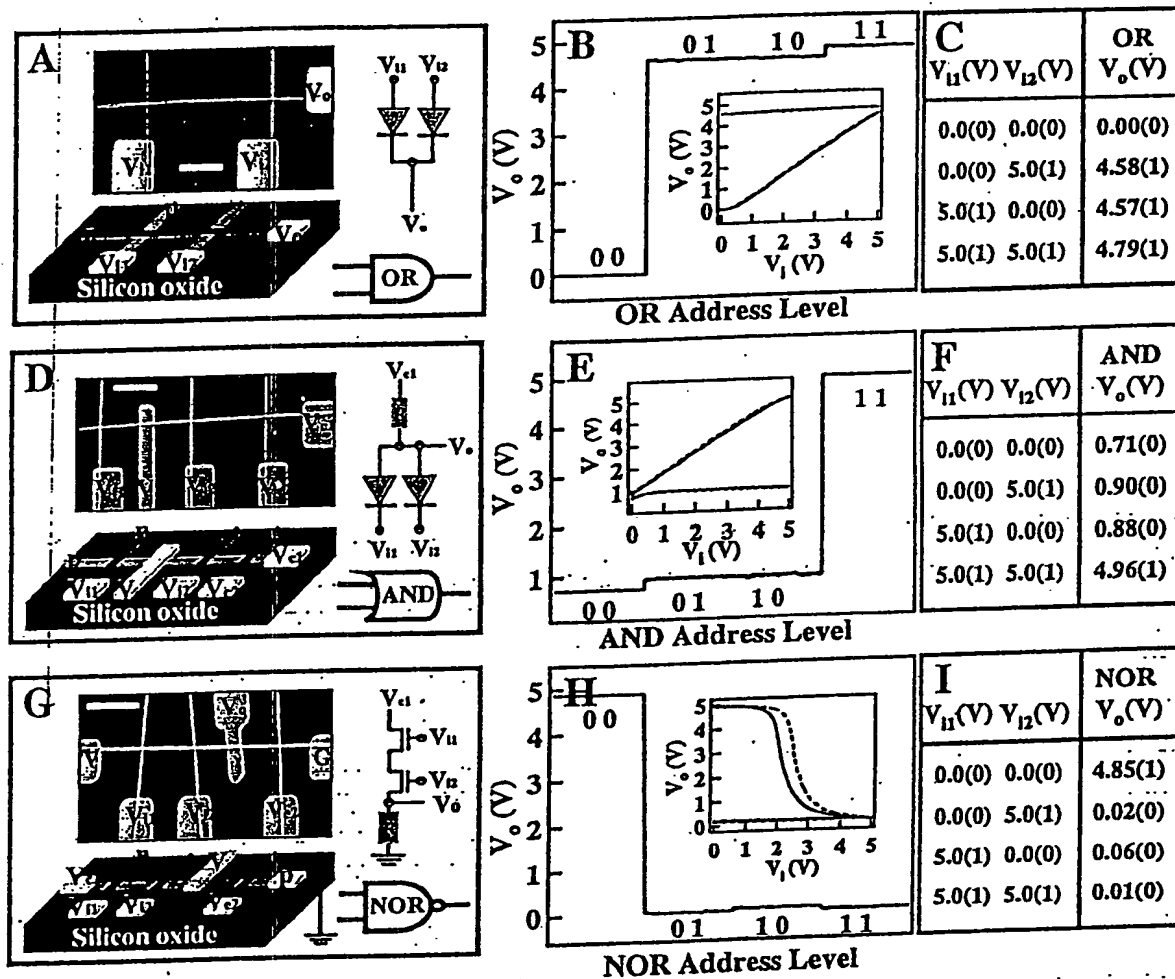


Figure 61

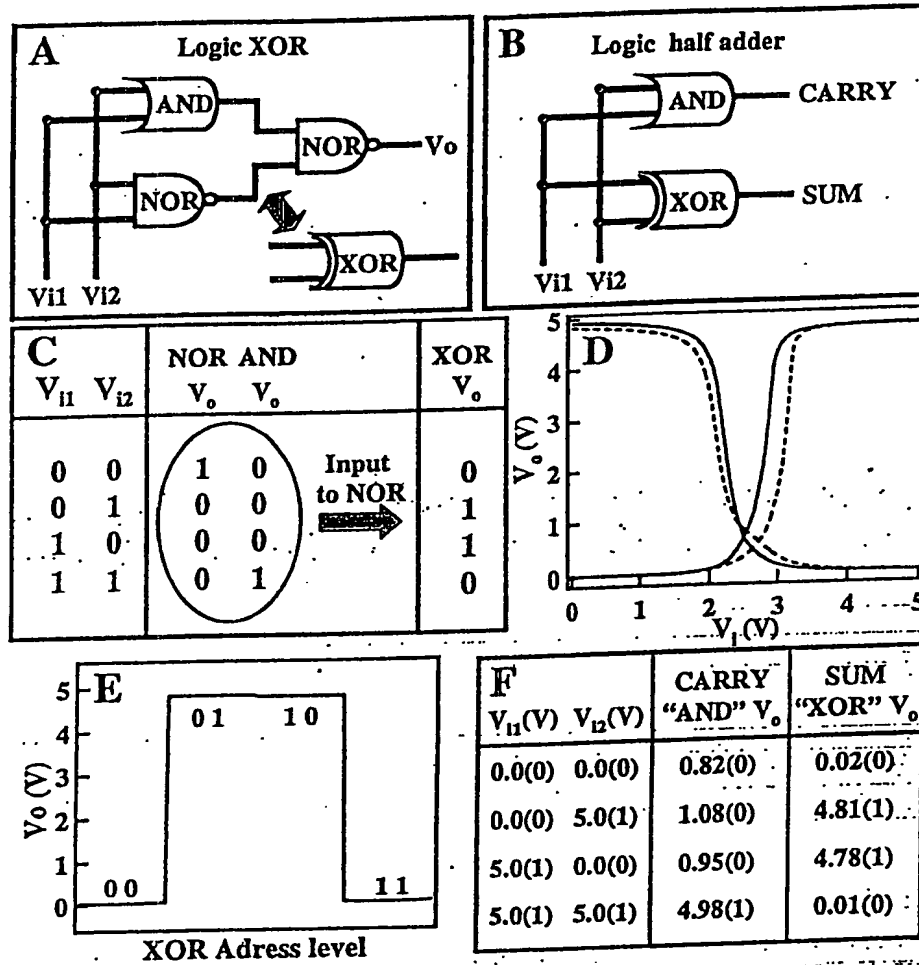


Figure 62

Fig. 63A

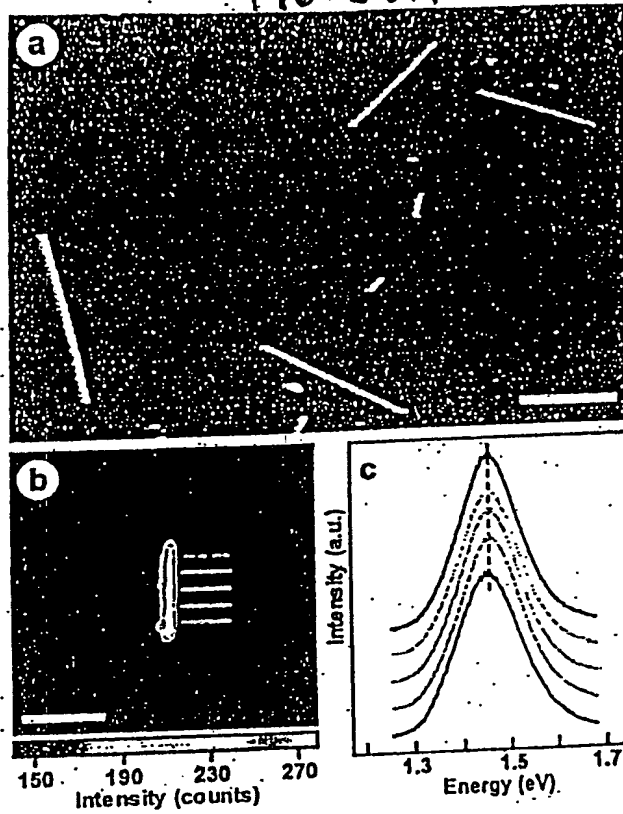


Fig 63B

Fig 63C



Fig 64A

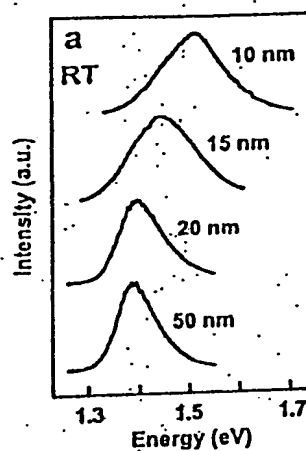


Fig 64B

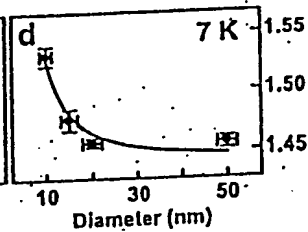
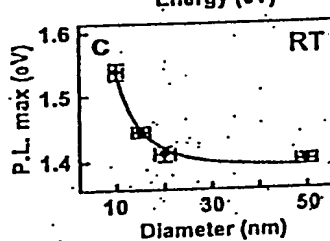
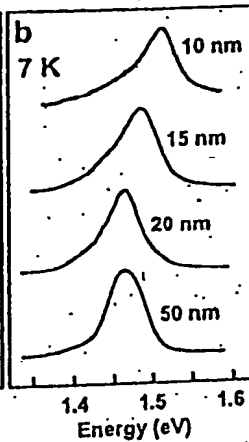


Fig 64C

Fig 64D

Fig 65A

Fig 65B

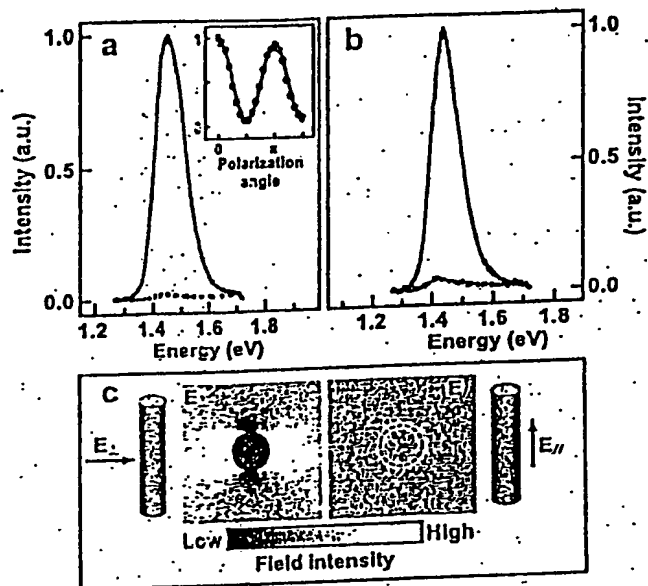


Fig 65C

Fig. 66A

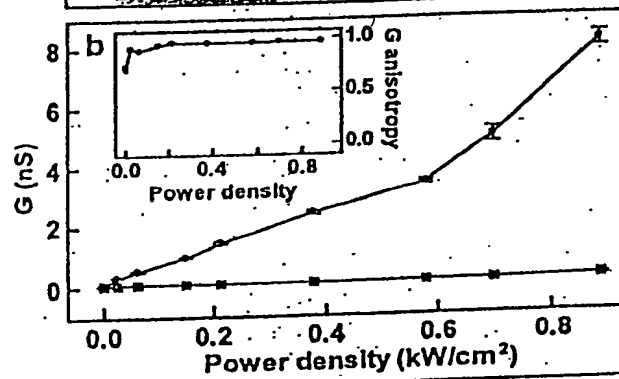
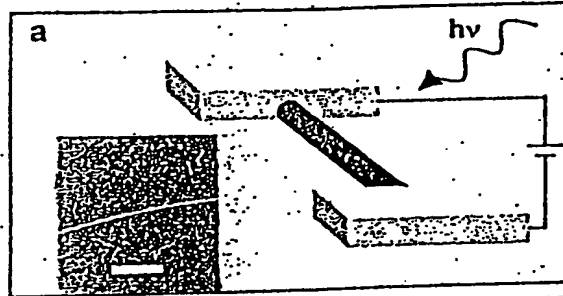


Fig. 66B

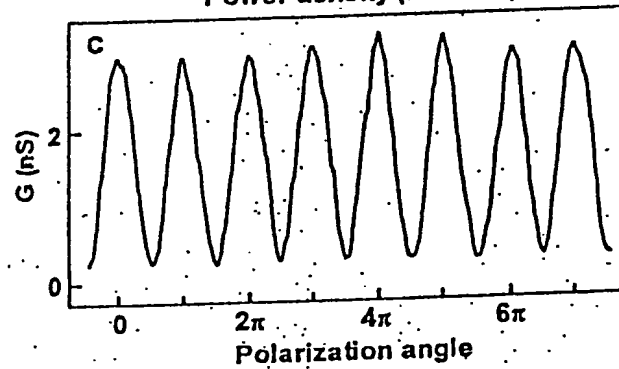


Fig. 66C

FIG. 67

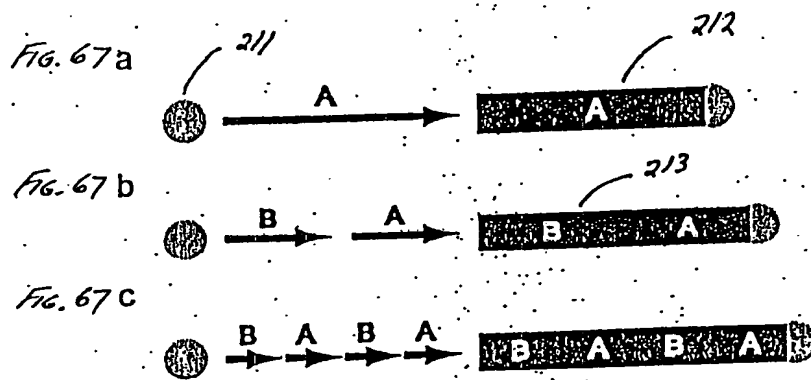


FIG. 68

Fig. 68a

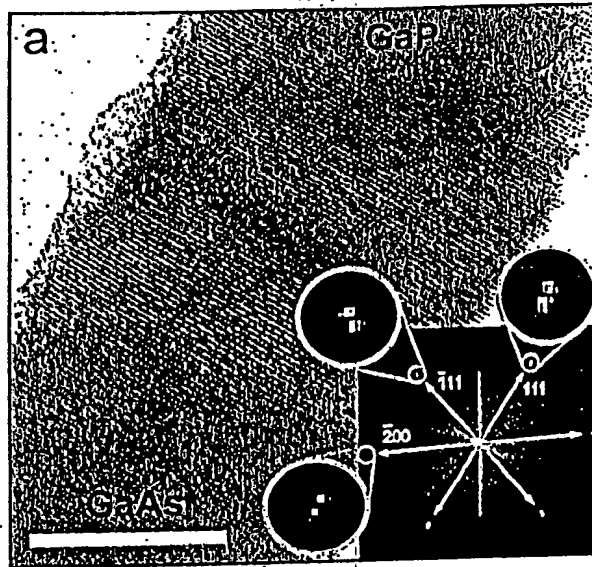


Fig 68b

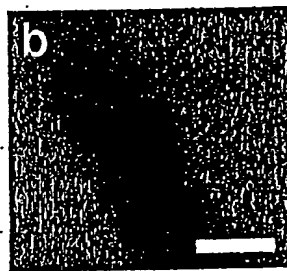


Fig 68c

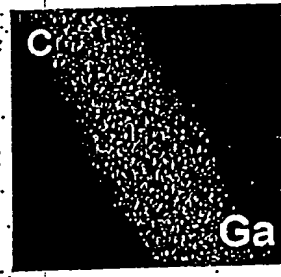


Fig 68d

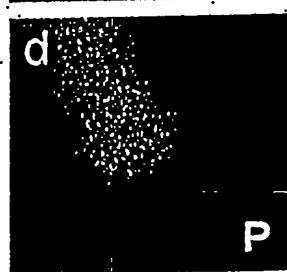


Fig. 68E

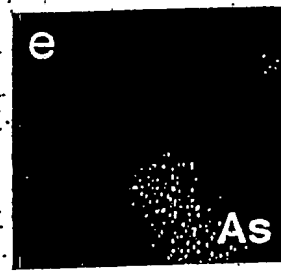
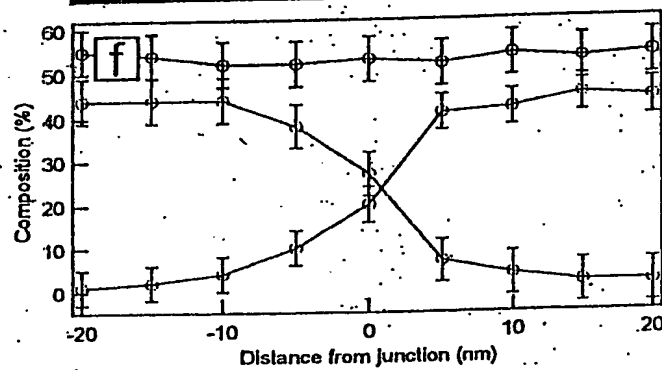
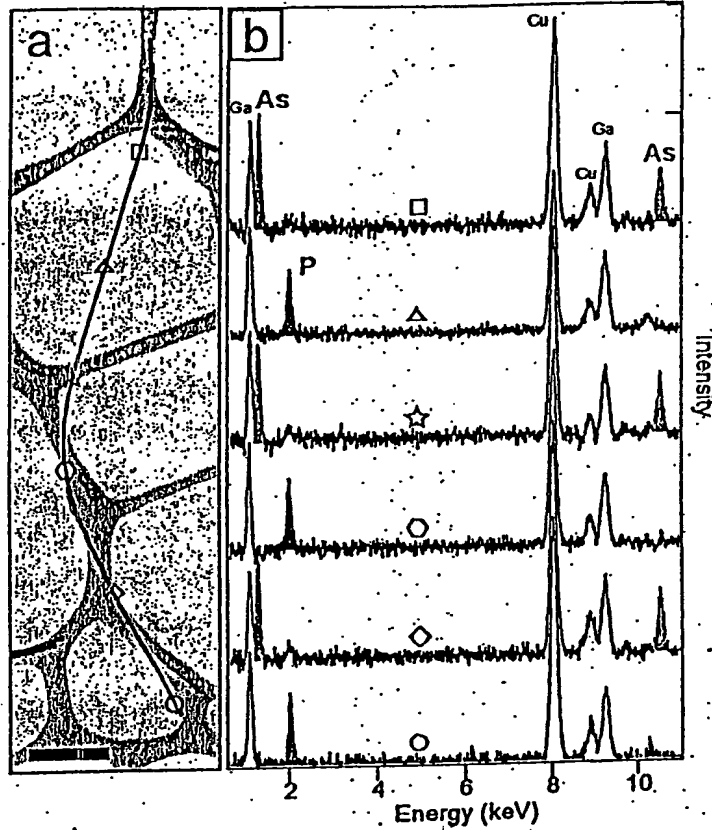


Fig. 68F

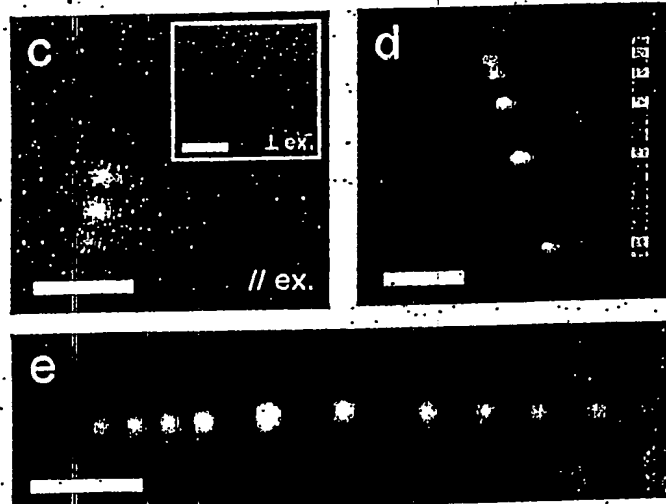


*Fig. 69*



*Fig. 69A*

*Fig. 69B*

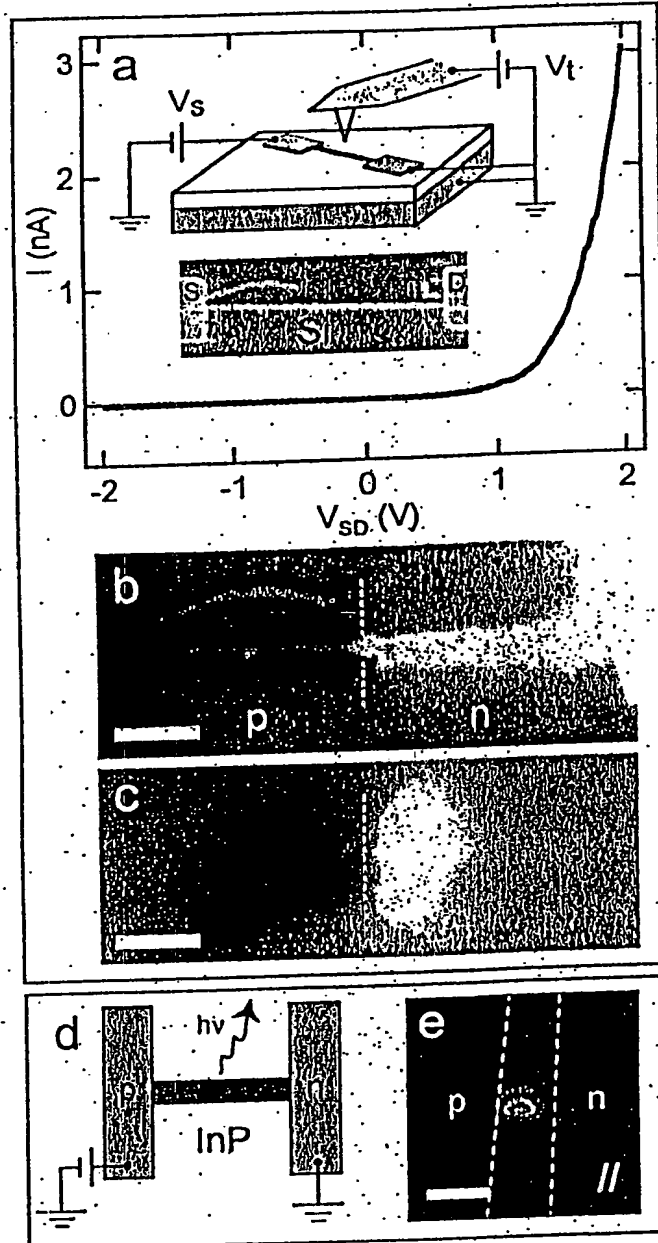


*Fig. 69C*

*Fig. 69D*

*Fig. 69E*

*Fig. 70*



*Fig. 70A*

*Fig. 70B*

*Fig. 70C*

*Fig. 70D*

*Fig. 70E*

## General fabrication approaches:

### I. Direct growth

(a) Define nanocluster catalyst

(b) Initial LCG semiconductor growth



(c) Second LCG semiconductor growth

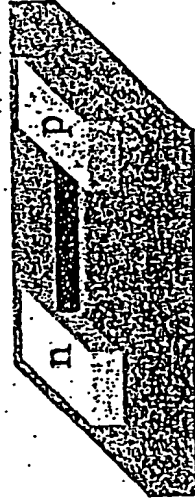


(d) Repeat (b) or (c) as desired

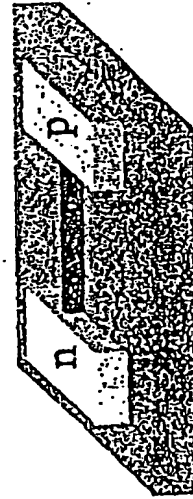


### II. Post-synthesis functionalization

(a) Fabricate nanowire device



(b) Introduce dopants by annealing





Semiconductor heterojunctions can be synthesized within single wires by changing the semiconductor material during growth.

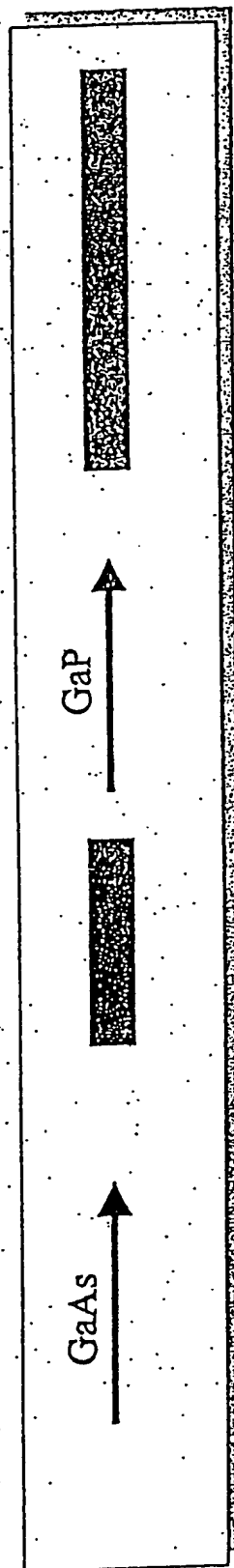
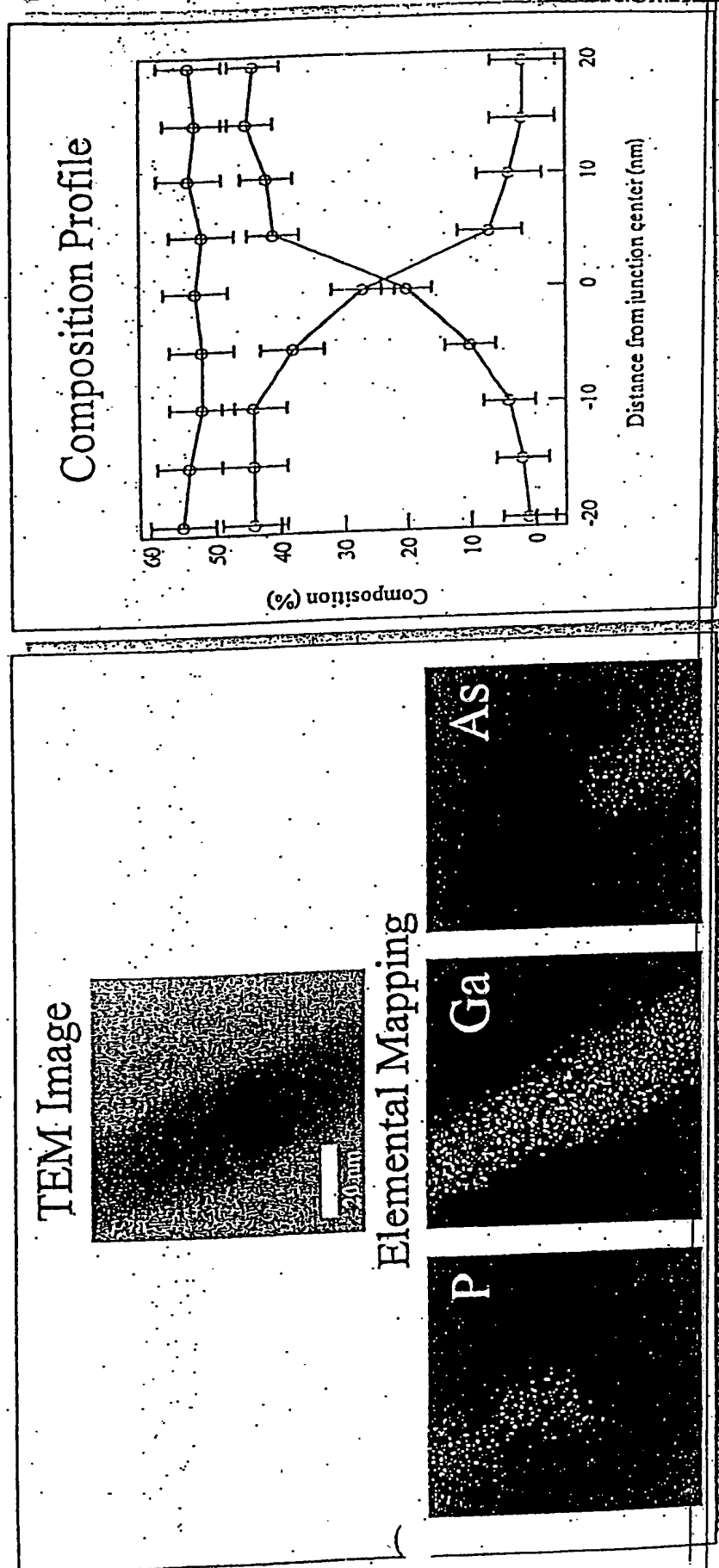
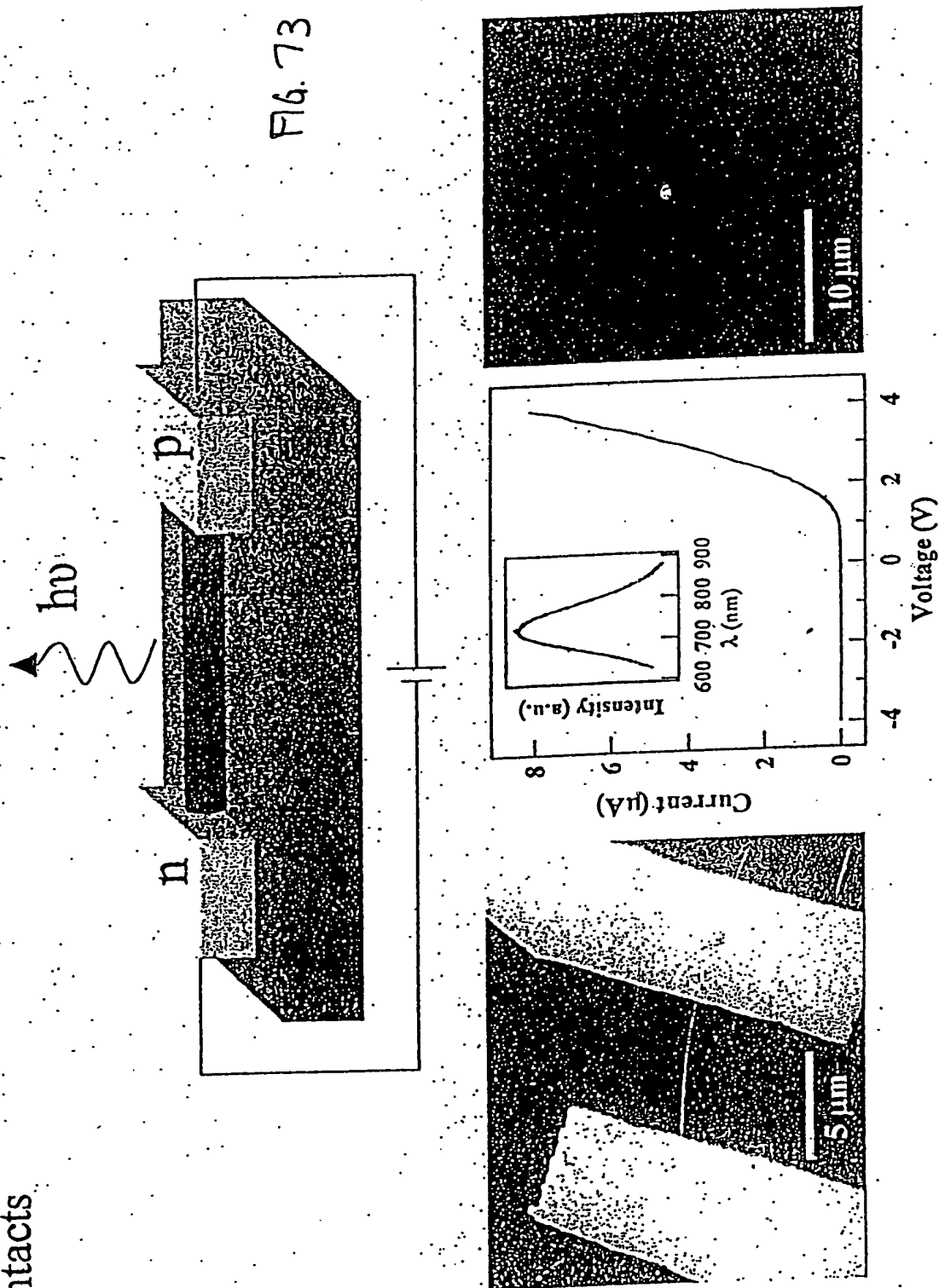


Fig. 72



Single nanowire light emitting diode created by introduction of dopants from contacts



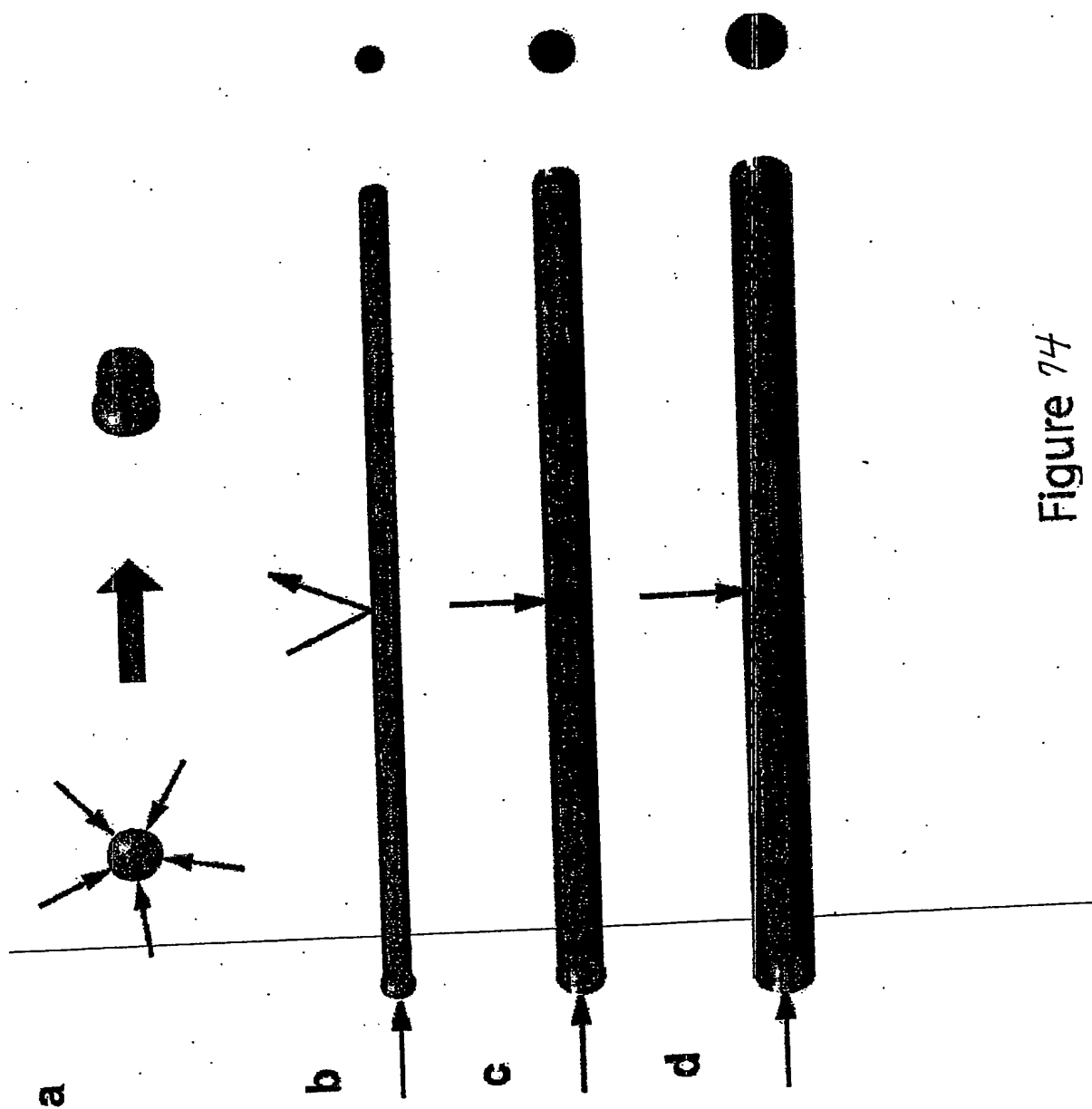


Figure 74

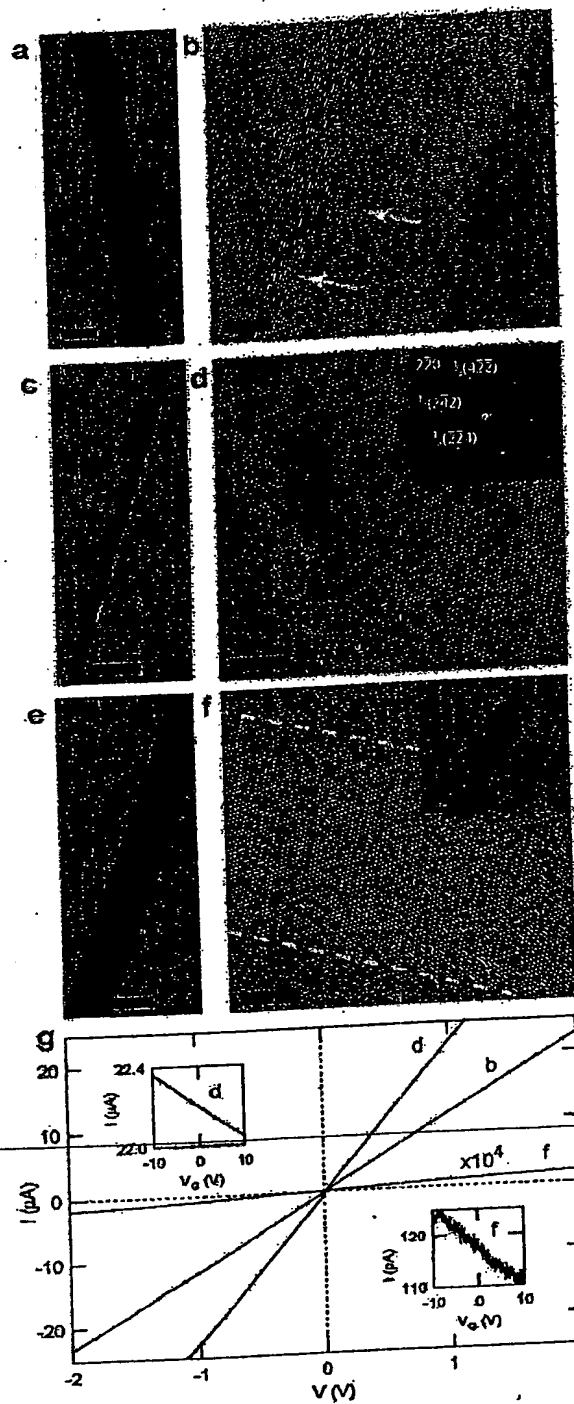


Figure 75

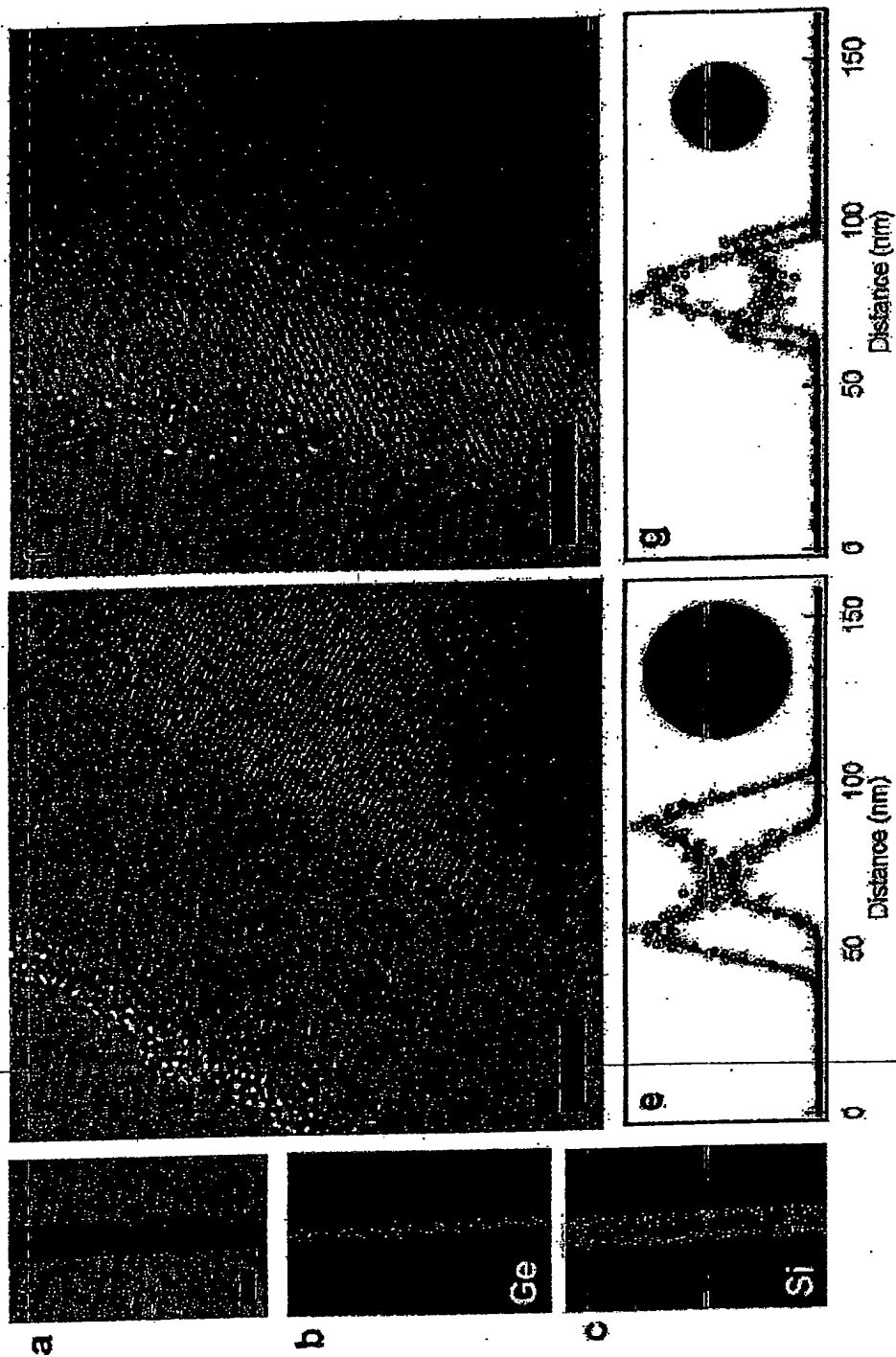


Figure 7c

H0498.70187US01

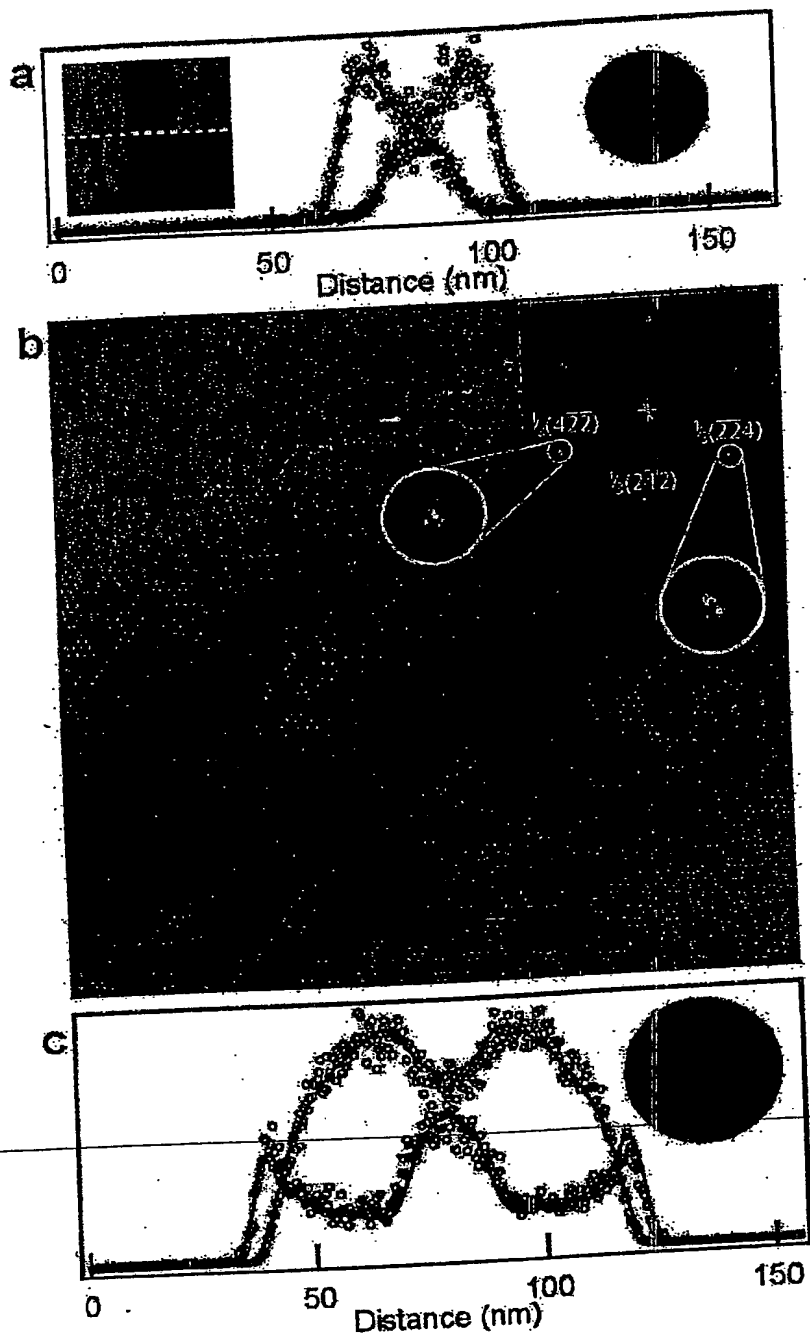


Figure 77

NANOSCALE WIRES AND RELATED  
DEVICES

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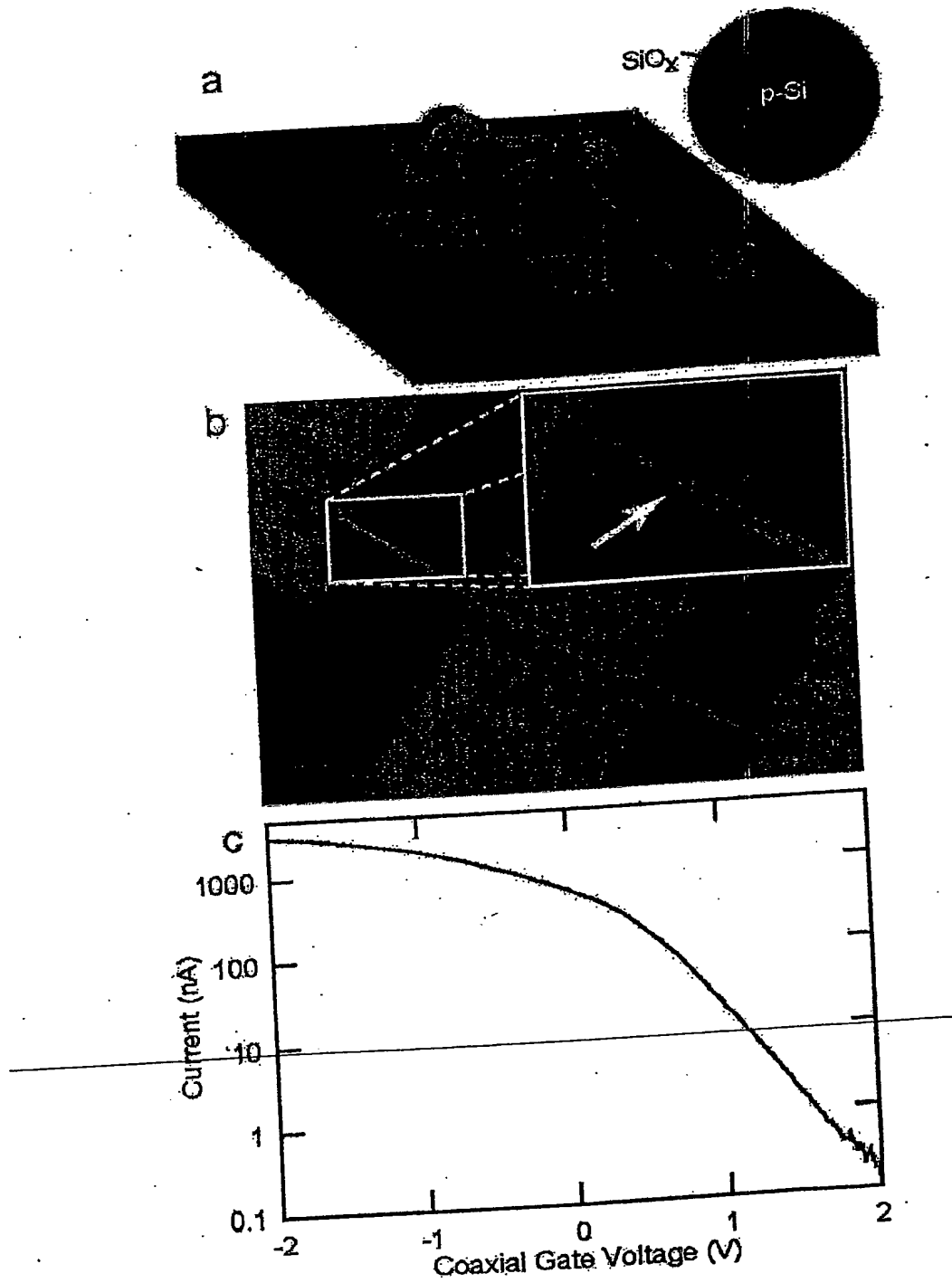


Figure 78